RD-15 65W 2C1A Charger Test Report

Reference Design Description

This test report of SZ-RD15-65W reference design describes a 65 W multi-port USB Type-C (2C) and USB Type-A (1A) universal input offline power supply with adaptive power sharing capabilities among the two Type-C USB ports for programmable output voltages of 5V/3A, 9V/3A, 12V/3A, 15V/3A, 20V/3.25A and one Type-A USB port for programmable output voltages of 5V/3A, 9V/2A, and 12V/1.5A. The power supply uses Silanna SZ1131 (Flyback PWM controller with integrated clamp circuit) and Silanna SZPL3002A (65W DCDC controller with integrated USB-PD Port IC). This design shows the high-power density and efficiency that can be achieved due to the high level of integration of the SZ1131 controller and the high switching frequency operation of SZPL3002A synchronous buck controller incorporated with intelligent USB-PD controller.

This document contains the power supply specification, schematic, bill-of-materials, transformer documentation, printed circuit layout, and performance data.

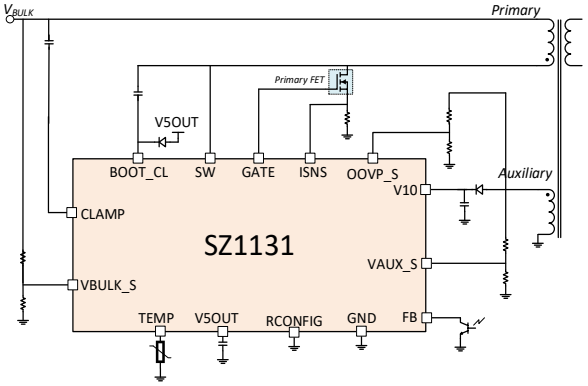
Key Specs	
Input	90-265 Vac
Output Voltages	USB-C PDO: 5 V, 9 V, 12 V, 15 V, 20 V USB-A QC 3.0: 5 V, 9 V, 12 V
Max Output Current	USB Type-C (Single Mode): 3 A at 5V, 9V, 12 V, 15V 3.25 A at 20 V USB Type-A (Single Mode): 3 A at 5 V, 2 A at 9 V, 1.5 A at 12 V
Max Output Power	USB-C PDO: 65 W (Single Mode) USB-A QC 2.0/3.0: 18 W (Single Mode) 2C+1A USB Ports: 65W with Adaptive Power Sharing across USB Ports
Output Ports	USB-PD 2C and QC 2.0/3.0 1A
Efficiency	>90% 65W Efficiency at 115Vac >90% 65W Efficiency at 230Vac

SZ1131 Features

- Integrated High Voltage Active Clamp FET, Active Clamp Driver, and Start-up Regulator
- Capable of Over 93.7% Efficiency
- Flat Efficiency Across Universal (90-265 VAC) Input Voltage and Load
- Tight Switching Frequency Regulation for Improved Input EMI Filter Utilization
- Up to 140 kHz Switching Frequency Operation
- OptiMode™ Cycle-by-Cycle Adaptive Digital Control
- Multi-Mode Operation (Burst Mode, Quasi-Resonant, Valley Mode Switching)
- Advanced Valley Mode Switching for low EMI
- Self-Tuning Valley Detection
- OTP, UVLO, OVLO, PCL, OPP and OSC Protections
- <30mW No Load Power Consumption of the IC
- Up to 65 W Output Power

SZ1131 Applications

- High-Power-Density USB-PD AC/DC Power Supplies

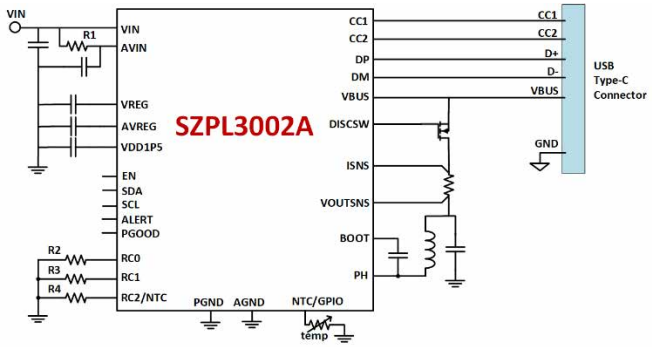


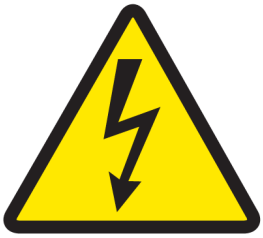
SZPL3002A Features

- Synchronous buck regulator with Switching Frequencies up to 2 MHz
- Integrated USB-PD Controller supporting USB-PD R3.0, PPS, BC1.2, QC 2.0/3.0/4.0/4.0+/5.0 Support
- Intelligent Multiport Power Sharing and Power Re-balancing
- High Efficiencies (>98%)
- Selectable Power Contract Configurations –reduces required programming
- Temperature Triggered Power Throttling
- VCONN power generation for e-Marked Cables
- Wide Input Voltage Range: 7.0 V to 27 V
- Supports Vout of 3.3 ~ 21.5 V, at 3.25 A
- Adjustable Cable Compensation
- UVLO/OCP/OVP/UVP/OTP Protections
- QFN 5 mm x 5 mm Thermally Enhanced Package

SZPL3002A Applications

- AC/DC Chargers with USB-PD Support
- Multiple Output USB-PD Charging Strips
- USB-PD Outputs in Displays and TVs
- Docking Stations and Laptops





Disclaimers:

1. **Caution – High Voltage Operation: Lethal high voltages are present when this evaluation board is powered from AC mains. Improper contact with high voltages could lead to electrical shock, burn and/or fire hazards, risking property damage, personal injury, and death.**
2. **Evaluation Purpose Only: This evaluation board is intended for evaluation purpose only and not for commercial use. Care must be taken when testing the board, and an isolation transformer should be utilized.**
3. **Patents: The evaluation board design, along with circuits shown in this test report, may be covered by one or more U.S. and foreign existing/pending patents.**

Contents

Power Supply Specifications

The evaluation board performance data presented in this report exceeds the power supply specifications listed in the following table.

Description	Symbol	Min.	Typ.	Max.	Units	Comments
Input						
Voltage	V_{in}	90	115/230	265	VAC	2 Wire Input
Frequency	f_{line}	47	60/50	63	Hz	
Output (USB Type-C)						
Max Current (20 V)	I_{out_max}			3.25	A	Single Port Operation
Max Current (5 V, 9 V, 12 V)	I_{out_max}			3		
Output (USB Type-A)						
Max Current (5 V)	I_{out_max}			3	A	Single Port Operation
Max Current (9 V)	I_{out_max}			2	A	
Max Current (12 V)	I_{out_max}			1.5	A	
Output Power						
Master USB Type-C	P_{out}			65	W	Single Port Operation
Slave USB Type-C	P_{out}			65	W	
Slave USB Type-A	P_{out}			18	W	
Total Output Power Continuous (2C1A)	P_{out}			65	W	Adaptive Power Sharing
DoE Level VI 4-Point Average Efficiency – Master USB-C Port						
5 V	η_{ave_5V}	76.41%	81.12%		%	DoE Level VI 4-point (25%, 50%, 75%, 100%) Average Efficiency 115 Vac, 25°C ambient
9 V	η_{ave_9V}	80.82%	85.92%		%	
12 V	η_{ave_12V}	82.98%	87.57%		%	
15 V	η_{ave_15V}	84.65%	89.11%		%	
20 V	η_{ave_20V}	86.00%	90.72%		%	
DoE Level VI 4-Point Average Efficiency – Slave USB-C Port						
5 V	η_{ave_5V}	76.41%	80.94%		%	DoE Level VI 4-point (25%, 50%, 75%, 100%) Average Efficiency 115 Vac, 25°C ambient
9 V	η_{ave_9V}	80.82%	85.97%		%	
12 V	η_{ave_12V}	82.98%	87.76%		%	
15 V	η_{ave_15V}	84.65%	89.03%		%	
20 V	η_{ave_20V}	86.00%	90.69%		%	
DoE Level VI 4-Point Average Efficiency – Slave USB-A Port						
5 V	η_{ave_5V}	76.41%	80.53%		%	DoE Level VI 4-point (25%, 50%, 75%, 100%) Average Efficiency 115 Vac, 25°C ambient
9 V	η_{ave_9V}	77.78%	83.97%		%	
12 V	η_{ave_12V}	77.78%	84.74%		%	
No-Load Input Power	P_{in}		161.30	300	mW	230 Vac, 25°C ambient

Table 1: Key Specifications

NOTE: The circuit board needs to be evaluated for additional tests, such as ESD and Line Surge to use the evaluation board design presented in this test report as a charger/adapter. Furthermore, the layout of the board needs to be adjusted according to the target shape and form factor of the end application.

Reference Design Board Pictures

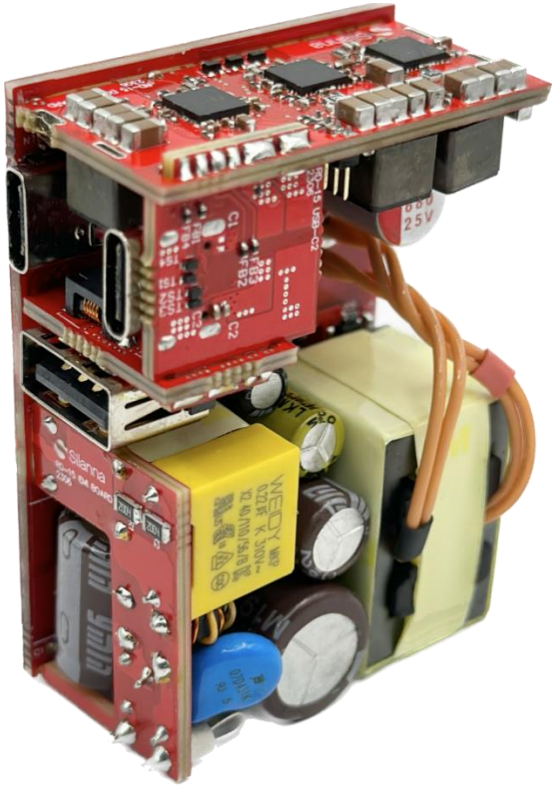


Figure 1: Top Side of the Reference Design Board

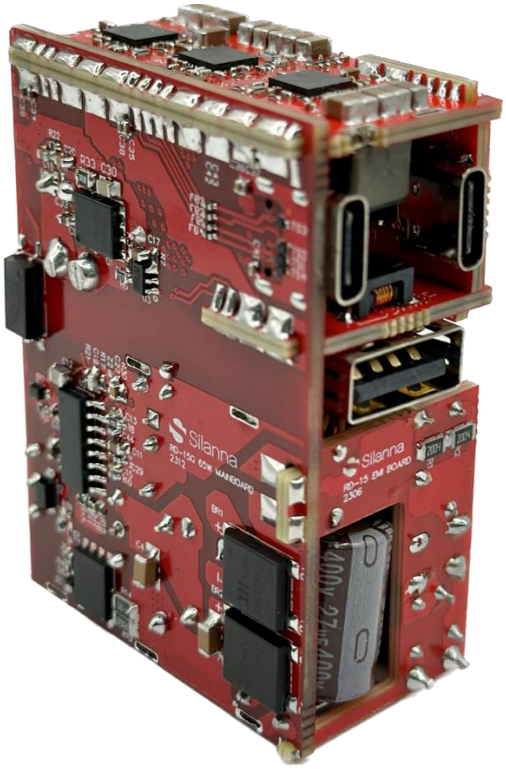


Figure 2: Bottom Side of the Reference Design Board

Schematic Diagram

Mainboard with Master USB-C Port

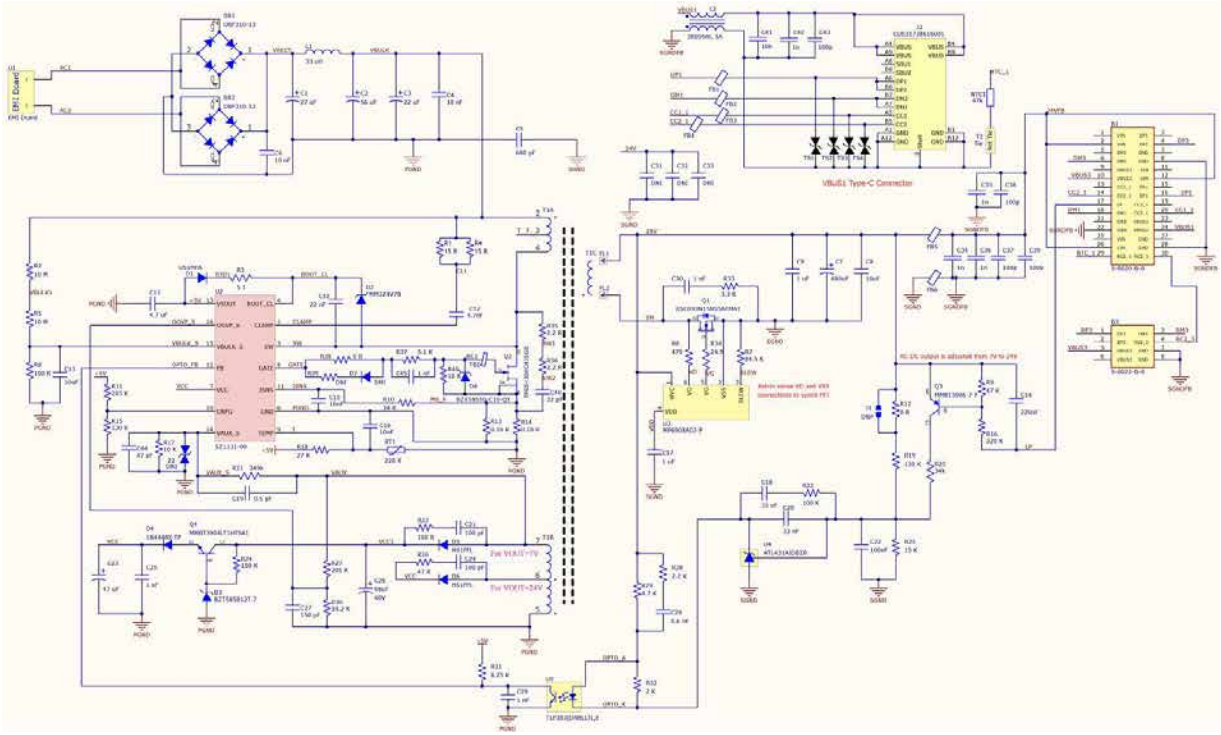


Figure 3: Mainboard with Master USB-C Port Schematic Diagram

DCDC Daughter Board

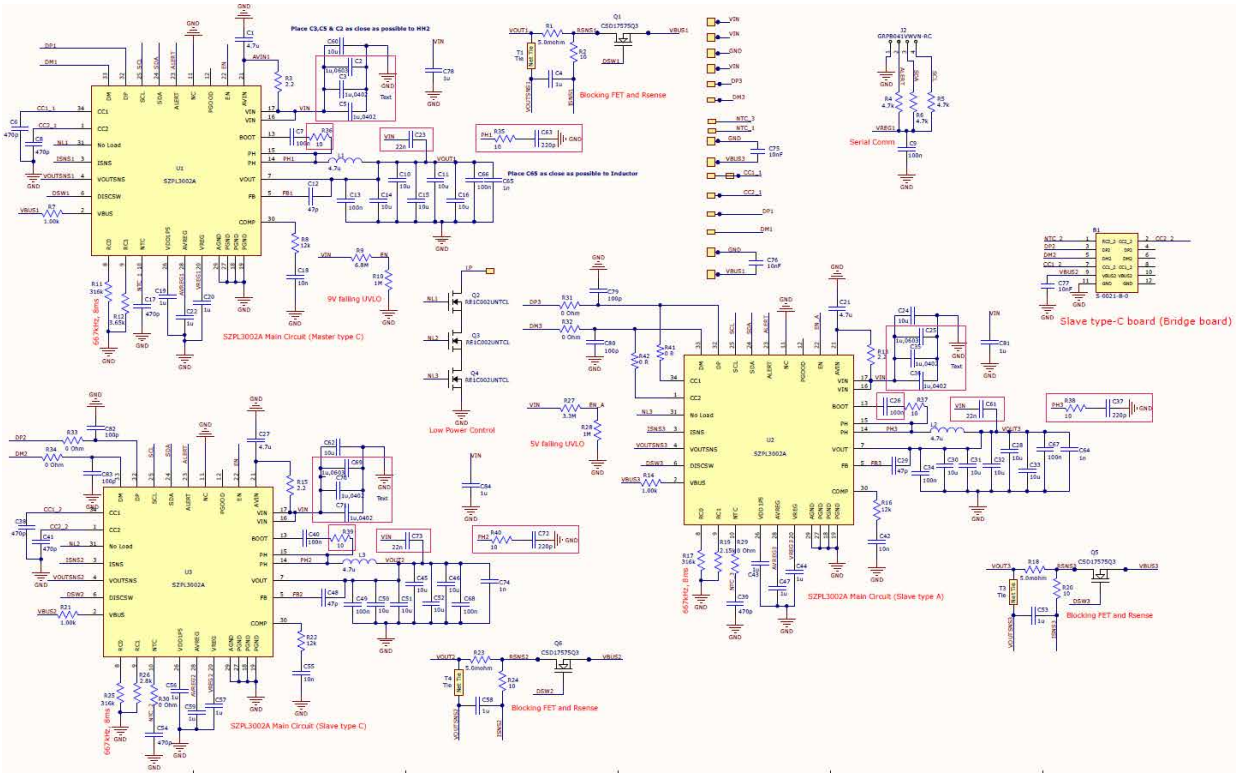


Figure 4. DC-DC Blocks for Master USB-C, Slave USB-C, Slave USB-A Ports Schematic Diagram

Slave USB-C Port Daughter Board

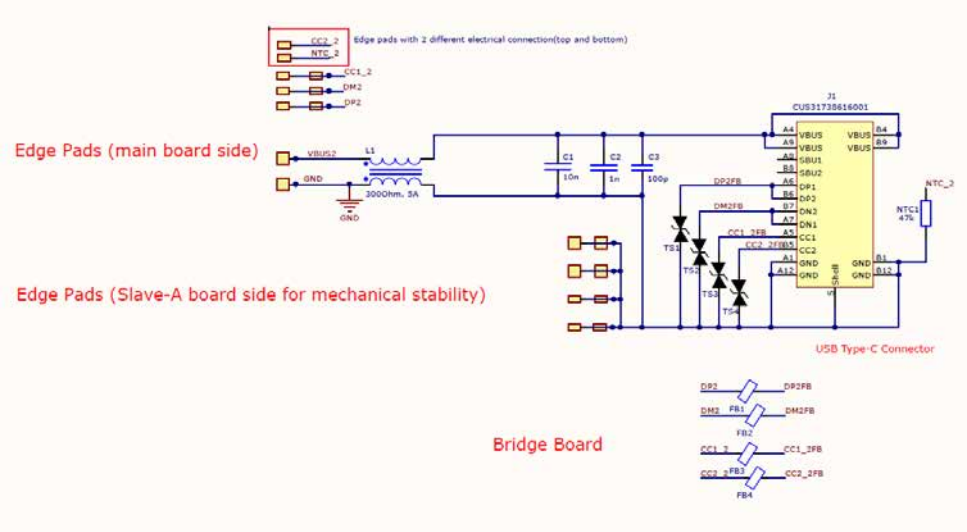


Figure 5. Slave USB-C Port Daughter Board

Slave USB-A Port Daughter Board

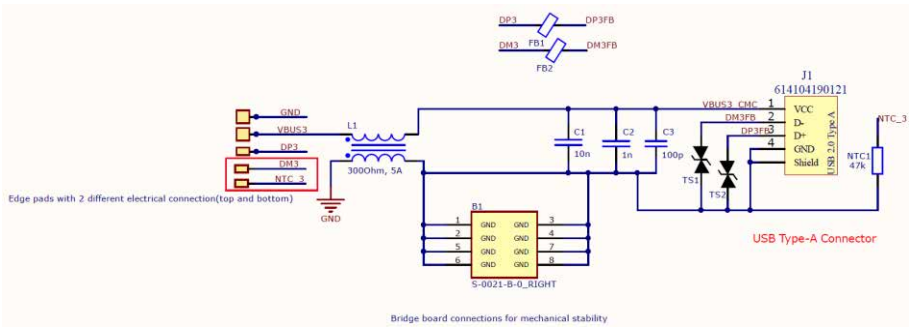


Figure 6. Slave USB-A Port Daughter Board

Input EMI Board

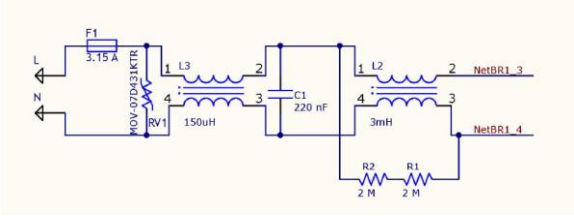


Figure 7. Input EMI Board

PCB Layout

Mainboard with Master USB-C Port

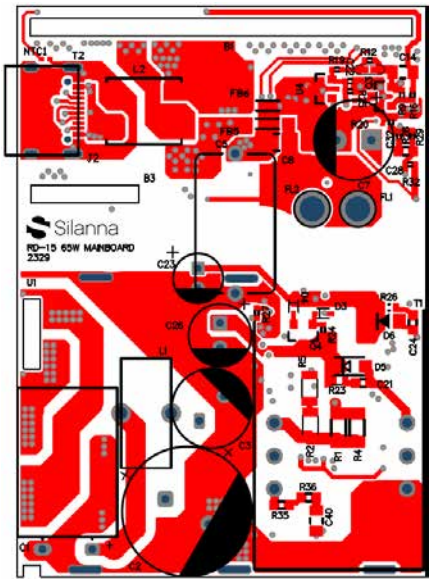


Figure 8. Mainboard with Master USB-C Port (Top Layer)

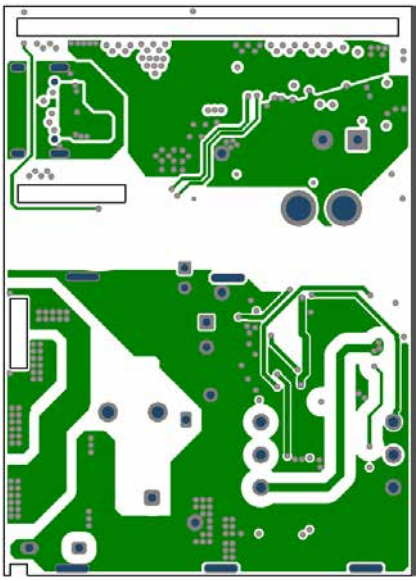


Figure 10. Mainboard with Master USB-C Port (Inner Layer 2)

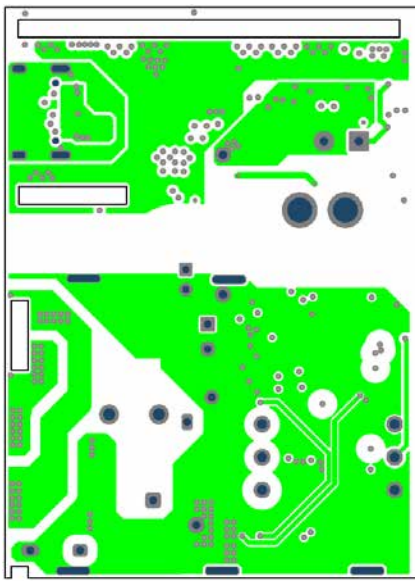


Figure 9. Mainboard with Master USB-C Port (Inner Layer 1)

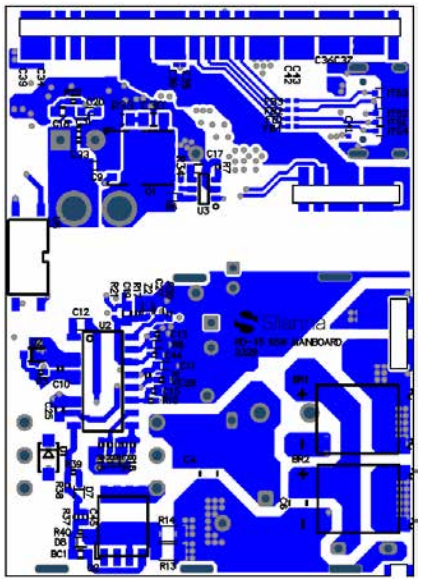


Figure 11. Mainboard with Master USB-C Port (Bottom Layer)

DC-DC Block Daughter Board

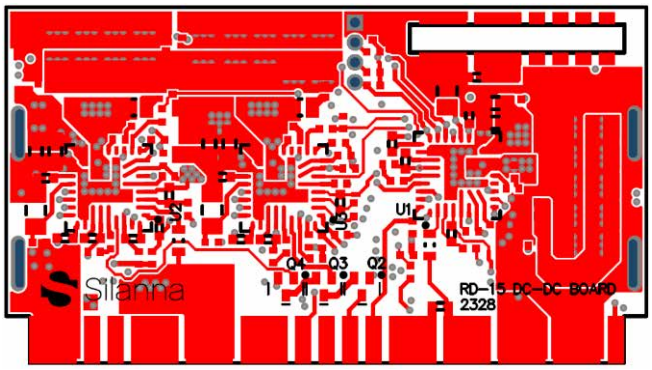


Figure 12. DC-DC Block Daughter Board (Top Layer)

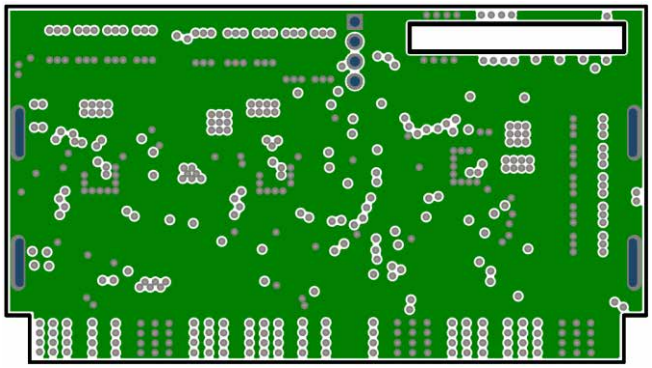


Figure 14. DC-DC Block Daughter Board (Inner Layer 2)

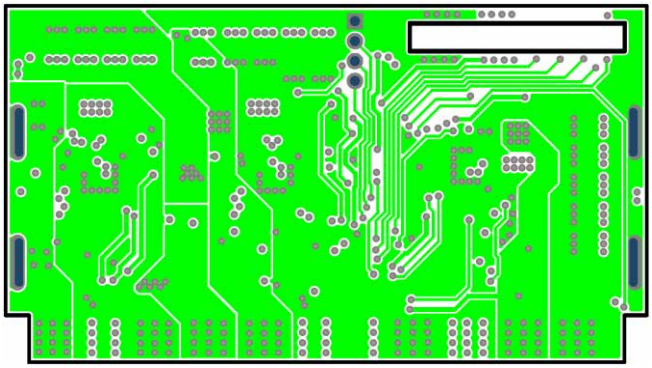


Figure 13. DC-DC Block Daughter Board (Inner Layer 1)

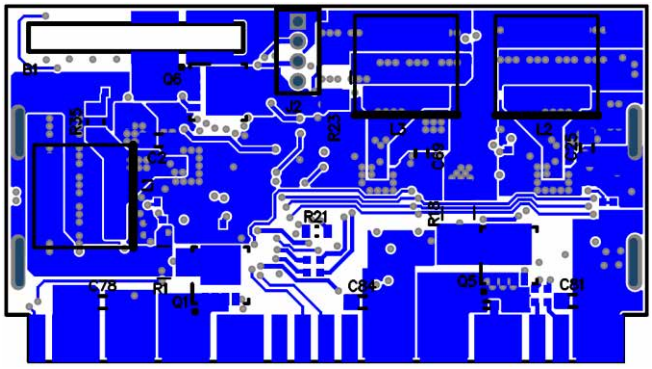


Figure 15. DC-DC Block Daughter Board (Bottom Layer)

Slave USB-C Port Daughter Board

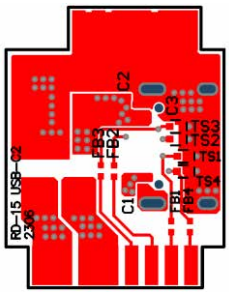


Figure 16. Slave USB-C Port Daughter Board (Top Layer)

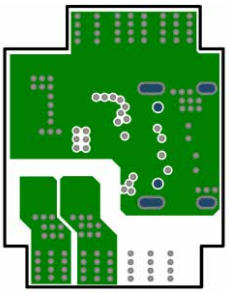


Figure 17. Slave USB-C Port Daughter Board (Inner Layer 1)

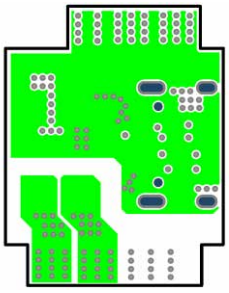


Figure 18. Slave USB-C Port Daughter Board (Inner Layer 2)

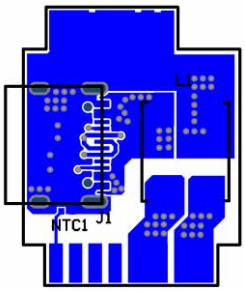


Figure 19. Slave USB-C Port Daughter Board (Bottom Layer)

Slave USB-A Port Daughter Board

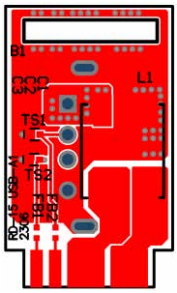


Figure 20. Slave USB-A Port Daughter Board (Top Layer)

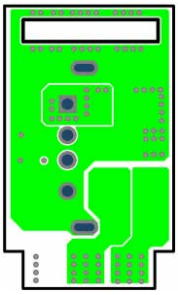


Figure 22. Slave USB-A Port Daughter Board (Inner Layer 2)

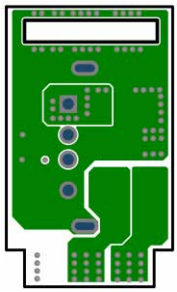


Figure 21. Slave USB-A Port Daughter Board (Inner Layer 1)

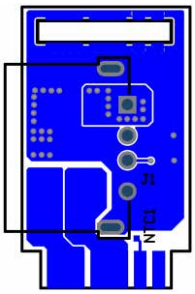


Figure 23. Slave USB-A Port Daughter Board (Bottom Layer)

Input EMI Board

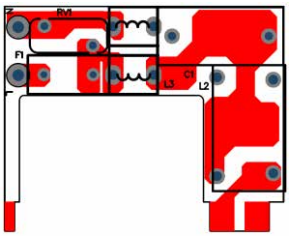


Figure 24. Input EMI Board (Top Layer)

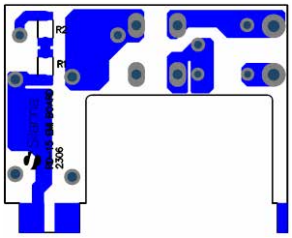


Figure 25. Input EMI Board (Bottom Layer)

Bill of Materials (BOM)

Designator	Description	Manufacturer	Manufacturer Part Number
Mainboard with Master USB-C port			
BC1	RES 0 OHM JUMPER 1/10W 0603	Yageo	RC0603JR-070RL
BR1, BR2	BRIDGE RECT 1PHASE 1KV 3A DBF	Diodes Incorporated	DBF310-13
C1	CAP ALUM 27UF 20% 400V T/H	YMIN	KCX(27UF-10X15P5)
C2	CAP ALUM 56UF 20% 400V T/H	YMIN	KCX(56UF-13X19P5)
C3	CAP ALUM 22UF 20% 400V T/H	YMIN	KCX(22UF-8X18P3.5)
C4, C6	CAP CER 10000PF 630V X7R 1206	KEMET	C1206C103KBRACTU
C5	CAP CER 680PF 300VAC RADIAL	Murata Electronics	DE1B3KX681KB4BP01F
C7	CAP ALUM POLY 680UF 20% 25V T/H	KEMET	A750KW687M1EAAE016
C8	CAP CER 10UF 50V X7R 1206	TDK Corporation	CGA5L1X7R1H106K160AC
C9, C25	CAP CER 1UF 35V X7R 0603	Taiyo Yuden	GMK107AB7105KAHT
C10	CAP CER 0.022UF 50V X7R 0402	Yageo	CC0402KRX7R9BB223
C11	CAP CER 4.7UF 16V X7R 0603	Murata Electronics	GRM188Z71C475KE21D
C12	CAP CER 4700PF 450V C0G 0805	TDK Corporation	C2012C0G2W472J125AA
C13, C15, C16, C41	CAP CER 10000PF 50V X7R 0402	Murata Electronics	GRM155R71H103KA88D
C14	CAP CER 0.22UF 50V X7R 0805	Taiyo Yuden	UMK212B7224KG-T
C17	CAP CER 1UF 25V X7R 0603	Samsung Electro-Mechanics	CL10B105KA8NNNC
C18, C20	CAP CER 0.033UF 50V X7R 0603	Yageo	CC0603KRX7R9BB333
C19	CAP CER 0.5PF 100V C0G/NP0 0603	KEMET	C0603C508B1GAC7867
C21, C24	CAP CER 100PF 200V NPO 0603	Yageo	CC0603JRNPOABN101
C22	CAP CER 0.1UF 50V X7R 0402	TDK Corporation	C1005X7R1H104K050BB
C23	CAP ALUM 47UF 20% 25V RADIAL	Rubycon	25YXJ47MTA5X11
C26	CAP ALUM 68UF 80V 20% T/H	YMIN	LKMC1501K680MF
C27	CAP CER 150PF 50V C0G/NPO 0603	Yageo	CC0603JRNPO9BN151
C28	CAP CER 5600PF 25V X7R 0603	KEMET	C0603C562K3RAC7867
C29	CAP CER 1000PF 25V C0G/NP0 0402	Murata Electronics North America	GRM1555C1E102JA01D
C30	CAP CER 1000PF 200V X7R 0805	Yageo	CC0805KRX7RABB102
C34, C35, C36, C42	CAP CER 1000PF 50V C0G 0402	TDK	C1005C0G1H102J050BA
C37, C38, C39, C43	CAP CER 100PF 100V C0G 0402	TDK Corporation	C1005C0G2A101J050BA
C40	CAP CER 22PF 1KV C0G/NP0 0805	KEMET	C0805C220JDGAC7800
C44	CAP CER 47PF 50V C0G/NP0 0402	Murata Electronics	GCM1555C1H470JA16D
C45	CAP CER 1000PF 50V X7R 0402	Yageo	CC0402KRX7R9BB102
D1	DIODE GEN PURP 1KV 1A SOD123FA	ON Semiconductor	US1MFA
D2	DIODE ZENER 4.7V 200MW SOD323F	ON Semiconductor	MM3Z4V7B
D3	DIODE ZENER 12V 350MW SOD523	Diodes Inc.	BZT585B12T-7
D4	DIODE GEN PURP 75V 250MA SOD523	Micro Commercial Co	1N4448X-TP
D5, D6	DIODE GEN PURP 300V 1A SOD123F	Taiwan Semiconductor Corporation	HS1FFL
D8	DIODE ZENER 10V 300MW SOD523	Nexperia USA Inc.	BZX58550-C10-QX
FB1, FB2, FB3, FB4	FERRITE BEAD 1800OHM 0402 1LN	Murata Electronics	BLM15HD182SZ1D
FB5, FB6	FERRITE BEAD 56 OHM 1806 1LN	Taiyo Yuden	FBMJ4516HM560NTV
J2	CONN USB-C FEMALE 16P SMT	CSCONN	CUS31738616001
L1	FIXED IND 32UH T/H	Wurth Electronics Inc.	7447052
L2	CMC 5A 2LN 300 OHM SMD	TDK Corporation	ACM7060-301-2PL-TL01
NTC1	THERMISTOR NTC 47KOHM 4050K 0402	Murata Electronics	NCP15WB473F03RC
Q1	MOSFET N-CH 150V 87A TDSON-8	Infineon Technologies	BSC093N15NS5ATMA1

Designator	Description	Manufacturer	Manufacturer Part Number
Q2	650V SuperGaN® GaN FET in PQFN (source tab)	Transphorm	TP65H300G4JSGB
Q3	TRANS PNP 40V 0.2A SOT23-3	Diodes Incorporated	MMBT3906-7-F
Q4	TRANS NPN 40V 0.2A SOT23	Infineon Technologies	MMBT3904LT1HTSA1
R1, R4	RES 15 OHM 1% 1/2W 1206	Stackpole Electronics Inc	RNCP1206FTD15R0
R2, R5	RES SMD 10M OHM 0.5% 1/4W 1206	Vishay Dale	CRCW120610M0DHEAP
R3	RES 5.1 OHM 1% 1/16W 0402	Yageo	RC0402FR-075R1L
R6	RES SMD 470 OHM 1% 1/10W 0603	Yageo	RC0603FR-07470RL
R7	RES SMD 84.5K OHM 1% 1/16W 0402	Yageo	RC0402FR-0784K5L
R8	RES SMD 100K OHM 0.1% 1/10W 0603	Panasonic Electronic Components	ERA-3AEB104V
R9	RES SMD 47K OHM 1% 1/16W 0402	Yageo	RC0402FR-0747KL
R10	RES SMD 24 OHM 1% 1/16W 0402	Yageo	RC0402FR-0724RL
R16	RES SMD 220K OHM 1% 1/16W 0402	Yageo	RC0402FR-07220KL
R12	RES SMD 0 OHM JUMPER 1/16W 0402	Yageo	RC0402JR-070RL
R13	RES 0.16 OHM 1% 1/2W 1206	TE Connectivity Passive Product	RLP73K2BR16FTDF
R14	RES 0.18 OHM 1% 1/4W 1206	Yageo	RL1206FR-070R18L
R15	RES SMD 120K OHM 1% 1/16W 0402	TE Connectivity Passive Product	CRGCQ0402F120K
R17	RES SMD 10K OHM 1% 1/16W 0402	Yageo	RC0402FR-0710KL
R18	RES SMD 27K OHM 1% 1/16W 0402	Yageo	RC0402FR-0727KL
R15, R19	RES SMD 130K OHM 1% 1/16W 0402	Yageo	RC0402FR-07130KL
R20	RES 34K OHM 1% 1/16W 0402	Yageo	RC0402FR-0734KL
R21	RES 249K OHM 1% 1/16W 0402	Yageo	RC0402FR-07249KL
R22, R24	RES SMD 100K OHM 1% 1/16W 0402	Yageo	RC0402FR-07100KL
R23	RES SMD 100 OHM 1% 1/10W 0603	Yageo	RC0603FR-07100RL
R25	RES SMD 15K OHM 1% 1/16W 0402	Yageo	RC0402FR-0715KL
R26	RES SMD 47 OHM 1% 1/10W 0603	Yageo	RC0603FR-0747RL
R11, R27	RES SMD 205K OHM 1% 1/16W 0402	YAGEO	RC0402FR-07205KL
R28	RES SMD 2.2K OHM 1% 1/16W 0402	Yageo	RC0402FR-072K2L
R29	RES SMD 4.7K OHM 1% 1/16W 0402	Yageo	RC0402FR-074K7L
R30	RES SMD 10.2K OHM 1% 1/16W 0402	Stackpole Electronics Inc	RMCF0402FT10K2
R31	RES SMD 8.25K OHM 1% 1/16W 0402	Yageo	RC0402FR-078K25L
R32	RES SMD 2K OHM 1% 1/16W 0402	Yageo	RC0402FR-072KL
R33	RES SMD 3.3 OHM 1% 1/8W 0805	Yageo	RC0805FR-073R3L
R34	RES 24.9 OHM 1% 1/16W 0402	Yageo	RC0402FR-0724R9L
R35, R36	RES SMD 2.2 OHM 1% 1/10W 0603	Yageo	RC0603FR-072R2L
R37	RES 5.1K OHM 1% 1/16W 0402	Yageo	RC0402FR-075K1L
R40	RES SMD 10K OHM 1% 1/16W 0402	Yageo	RC0402FR-0710KL
R38	RES SMD 0 OHM JUMPER 1/16W 0402	Royalohm	0402WGF0000TCE
RT1	NTC THERMISTOR 220K 1% 0402	Panasonic Electronic Components	ERT-J0EV224F
T1	ACDC Transformer		
TS1, TS2, TS3, TS4	TVS, 5V, 9A, 150W	ST Micro	ESDALC5-1BM2
U2	Flyback PWM Controller with Integrated Active Clamp Circuit	Silanna Semiconductor	SZ1131-00
U3	FAST TURN-OFF INTELLIGENT RECTIF	Monolithic Power Systems Inc.	MP6908AGJ-P
U4	IC VREF SHUNT 36V 1% SOT23-3	Texas Instruments	ATL431AIDBZR
U5	OPTOISO 5KV TRANSISTOR SO6L	Toshiba Semiconductor and Storage	TLP383(D4BLLTL,E

Designator	Description	Manufacturer	Manufacturer Part Number
DC-DC Daughter Board			
C1, C21, C27	CAP CER 4.7UF 35V X7R 0805	TDK Corporation	C2012X7R1V475K125AC
C2, C3, C5, C25, C35, C36, C69, C70, C71	CAP CER 1UF 35V X7R 0603	TDK Corporation	CGA3E1X7R1V105K080AC
C4, C19, C20, C22, C43, C44, C47, C53, C56, C57, C58, C59, C78, C81, C84	CAP CER 1UF 10V X7R 0402	Murata Electronics	GRM155Z71A105KE01D
C6, C8, C17, C38, C39, C41, C54	CAP CER 470PF 50V C0G 0402	TDK Corporation	CGA2B2C0G1H471J050BA
C7, C9, C13, C26, C34, C40, C49, C66, C67, C68	CAP CER 0.1UF 50V X7R 0402	TDK Corporation	C1005X7R1H104K050BB
C10, C11, C14, C15, C16, C24, C28, C30, C31, C32, C33, C45, C46, C50, C51, C52, C60, C62	CAP CER 10UF 50V X7R 1206	TDK Corporation	C3216X7R1H106K160AC
C12, C29, C48	CAP CER 47PF 50V C0G/NP0 0402	Murata Electronics	GCM1555C1H470JA16D
C18, C42, C55	CAP CER 10000PF 50V X7R 0402	Murata Electronics	GRM155R71H103KA88D
C23, C61, C73	CAP CER 0.022UF 50V X7R 0402	Murata Electronics	GRM155R71H223KA12J
C37, C63, C72	CAP CER 220PF 50V C0G/NP0 0402	Murata Electronics	GCM1555C1H221FA16D
C64, C65, C74	CAP CER 1000PF 50V X7R 0402	TDK Corporation	C1005X7R1H102K050BA
C75, C76, C77	CAP CER 10000PF 50V X7R 0402	Murata Electronics	GRM155R71H103KA88D
C79, C80, C82, C83	CAP CER 100PF 16V C0G/NP0 0402	KEMET	C0402C101K4GACTU
J2	CONN HEADER VERT 4POS 1.27MM	Sullins Connector Solutions	GRPB041VWVN-RC
L1, L2, L3	INDUCTOR, 4.7UH, 10.2A, 9.1MOHM	Coilcraft	XGL6060-472MEB
Q1, Q5, Q6	MOSFET N-CH 30V 60A 8VSON	Texas Instruments	CSD17575Q3
Q2, Q3, Q4	MOSFET N-CH 20V 200MA EMT3F	Rohm	RE1C002UNTCL
R1, R18, R23	RES 0.005 OHM 2% 3/4W 1206	Susumu	KRL1632E-M-R005-G-T5
R2, R20, R24, R36, R37, R39	RES 10 OHM 1% 1/16W 0402	Yageo	RC0402FR-0710RL
R3, R13, R15	RES 2.2 OHM 1% 1/16W 0402	Yageo	RC0402FR-072R2L
R4, R5, R6	RES 4.7K OHM 1% 1/16W 0402	Yageo	RC0402FR-074K7L
R7, R14, R21	RES 1K OHM 1% 1/10W 0603	Yageo	RC0603FR-071KL
R8, R16, R22	RES 12K OHM 1% 1/16W 0402	Yageo	RC0402FR-0712KL
R9	RES SMD 6.8M OHM 1% 1/16W 0402	Vishay	CRCW04026M80FKED
R10, R28	RES 1M OHM 1% 1/16W 0402	Yageo	RC0402FR-071ML
R11, R17, R25	RES 316K OHM 1% 1/16W 0402	Yageo	RC0402FR-07316KL
R12	RES 3.65K OHM 1% 1/16W 0402	Yageo	RC0402FR-073K65L
R19	RES 2.15K OHM 1% 1/16W 0402	Yageo	RC0402FR-072K15L
R26	RES 2.8K OHM 1% 1/16W 0402	Yageo	RC0402FR-072K8L
R27	RES 3.3M OHM 1% 1/16W 0402	Yageo	RC0402FR-073M3L
R29, R30, R31, R32, R33, R34, R40, R41	RES 0 OHM JUMPER 1/16W 0402	Yageo	RC0402JR-070RL
R35, R38, R40	RES SMD 10 OHM 1% 1/2W 0805	Panasonic Electronic Components	ERJ-P06F10R0V
U1, U2, U3	65W DCDC SYNCHRONOUS BUCK CONTROLLER WITH INTEGRATED USB-PD PORT IC	Silanna Semiconductor	SZPL3002A
Slave USB-C Port Daughter Board			
C1	CAP CER 10000PF 50V X7R 0402	Murata Electronics	GRM155R71H103KA88D
C2	CAP CER 1000PF 50V C0G 0402	TDK Corporation	C1005C0G1H102J050BA

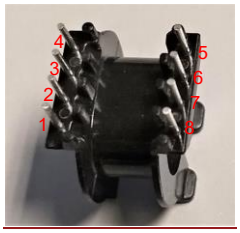
Designator	Description	Manufacturer	Manufacturer Part Number
C3	CAP CER 100PF 100V C0G 0402	TDK Corporation	C1005C0G2A101J050BA
FB1, FB2, FB3, FB4	FERRITE BEAD 1800OHM 0402 1LN	Murata Electronics	BLM15HD182SZ1D
J1	CONN USB-C FEMALE 16P SMT	CSCONN	CUS31738616001
L1	CMC 5A 2LN 300 OHM SMD	TDK Corporation	ACM7060-301-2PL-TL01
NTC1	THERMISTOR NTC 47KOHM 4050K 0402	Murata Electronics	NCP15WB473F03RC
TS1, TS2, TS3, TS4	TVS DIODE 5VWM SOD882	ST Micro	ESDALC5-1BM2
Slave USB-A Port Daughter Board			
C1	CAP CER 10000PF 50V X7R 0402	Murata Electronics	GRM155R71H103KA88D
C2	CAP CER 1000PF 50V C0G 0402	TDK Corporation	C1005C0G1H102J050BA
C3	CAP CER 100PF 100V C0G 0402	TDK Corporation	C1005C0G2A101J050BA
FB1, FB2	FERRITE BEAD 1800OHM 0402 1LN	Murata Electronics	BLM15HD182SZ1D
J1	CONN RCP USB2.0 TYPEA 4POS TH RA	Würth Elektronik	614104190121
L1	CMC 5A 2LN 300 OHM SMD	TDK Corporation	ACM7060-301-2PL-TL01
NTC1	THERMISTOR NTC 47KOHM 4050K 0402	Murata Electronics	NCP15WB473F03RC
TS1, TS2	TVS DIODE 5VWM SOD882	ST Micro	ESDALC5-1BM2
EMI Board			
C1	CAP FILM 220NF 10% 310V RAD	Weidy Industrial Electronic	W42Q3224KK6L00F0
F1	FUSE BRD MNT 3.15A 250VAC RADIAL	Bel Fuse Inc.	RST 3.15-BULK
L2	CUSTOM CMC 3MH		
L3	CUSTOM CMC 150UH		
R1, R2	RES SMD 2M OHM 1% 1/4W 1206	Yageo	RC1206FR-072ML
RV1	VARISTOR 275VAC 1.2KA DISC 7MM	Bourns Inc.	MOV-07D431KTR

Table 2. Bill of Materials

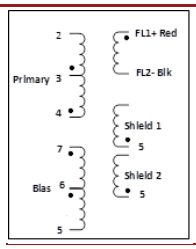
Magnetics Specification

Flyback Transformer

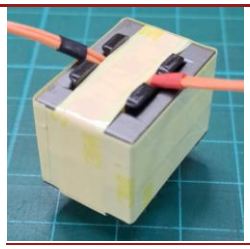
Transformer Specification



Pinout



Electrical



Winding Specification

Winding	1	2	3	4	5 Note 1	6 Note 1	7	8
Material*	AWG32	AWG34	AWG34	AWG34	LITZ 175 x44	LITZ 175 x 44	7.5 mm copper foil	AWG32
Turns	17	8	3	25.5	6	6	1	17
Parallel wires	2	1	1	2	1	1	1	2
Layers	1	1	1	1	1	1	1	1
Start Pin	4	7	6	5	FL1	FL1	5	3 (tie point)
End Pin	3 (tie point)	6	5	nc (notch of FL2)	FL2	FL2	nc	2
Comments	PRI1- First half of primary (tube needed)	Aux(tube needed). 2 & 3 are single tapped winding spread across bobbin evenly.		Shield 1	Secondary_1	Secondary_2	Shield 2	PRI1- Second half of primary (tube needed)
Insulation	1.5T Tape A	1.5T Tape A		1T Tape A	No Tape	1T Tape A	1.5T Tape A	2T Tape A

ELECTRICAL TEST PARAMETERS:

INDUCTANCE @ 100kHz/0.1VAC
L(2-4) =380µH ±5%
INDUCTANCE @ 100kHz/0.1VAC
SHORT PINTS: FL1, FL2
LL(2-4) = 6µH MAX
TURNS RATIO/POLARITY
APPLY: 1.00V @ 10kHz TO PINS (2-4)
Primary:Bias (5-6) = 0.083V ±3%
Primary:Secondary = 0.166V ±3%

Note1: Begin FL1 (Winding 5 and 6) on the right side of the bobbin (pin 5-8) and finish the w inding leftw ards. Flying leads should be 45 mm long. Mark FL1+ w ith red heat shrink, FL2- w ith black at end.
Note 2: Place belly band around the core covering the w indings: (1.) Wrap 1 layer of tape (2.) Wrap 1 layer of 7.5 mm Copper foil and connect to Pin 5 (3.) Wrap another layer of tape

Material List

Material	*Specification*	*Manufacturer*	*Mfr. Part Number*
Bobbin	ATQ2516		
Core	gap for 380uH (3C95 or equivalent)		
AWG32	Magnet wire, 130C, dual insulation layer	Any	
AWG34	Magnet wire, 130C, dual insulation layer	Any	
TIW Litz wire	Litz AWG44 x 175 strand Triple Insulated	Rubidue	TXXL175/44FXXX-2
TAPE	Insulating Yellow Polyester Tape	3M	3M-YELLOW-xx
Copper Foil	7.5mm wide copper foil tape	Any	
Shrink tubing	Red and Black for marking FL leads	Any	

DC RESISTANCE OHMS (Ω) @ 25°C
DCR: (2-4) = 0.6Ω MAX
DCR: (5-6)=0.2Ω MAX
DCR: (FL1-FL2) = 0.01Ω MAX

Notes:

Primary and secondary wires must not touch (>0.2mm)
All materials need to be min 130 °C, UL certified

Assembly:	Polyester tape
Glue / Varnish:	Not applicable for prototypes
Applicable Standard:	EN 61558
Isolation testing:	Windings 1, 2, 3, 4, 7 and 8 against 5 and 6: 1.5kVA

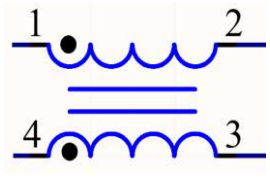
Title:	RD15 65W	Silanna Semiconductor North America
P/N:	RD15 ATQ2516	
Rev. 3	Eng:	
	Chk:	
	Date: June 7, 2023	Sheet 1 of 1

Figure 26. RD-15 Flyback Transformer Specification

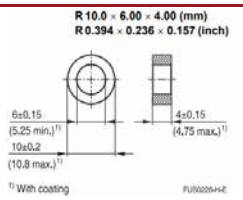
Input EMI CMC (L2)

CMC Specification

Pinout



Electrical



Core Dimension

Winding Specification:

Winding	1	2
Material*	AWG26	TIW 0.45mm
Turns	12	12
Parallel wires	1	1
Start Pin	1*	4*
End Pin	2	3
	CMC-Line	CMC-Neutral

Electrical Test Parameters:

INDUCTANCE @ 10kHz/0.1VAC
L(1-2) =3mH ±10%
L(3-4) =3mH ±10%
INDUCTANCE @ 10kHz/0.1VAC
LL(1-2) = 500nH MAX (3-4 shorted)

TURNS RATIO/POLARITY

APPLY: 1.00V @ 10kHz TO PINS (1-2)

Pin: (3-4) = 1V ±3%

DC RESISTANCE OHMS (Ω) @ 25°C
DCR: (1-2) = 0.06Ω MAX
DCR: (3-4) = 0.06Ω MAX

Material List

Material	*Specification*	*Manufacturer*	*Mfr. Part Number*
Core	10.4 x 6 x 6 mm	EPCOS - TDK Electronics	B64290L0038X046
AWG26	Magnet wire, dual insulation layer		
TIW 0.45mm	Triple Insulated Wire 0.45mm		

Notes:

All materials need to be min 130 °C, UL certified

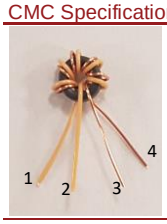
Assembly:	
Glue / Varnish:	Not applicable for prototypes
Applicable Standard:	EN 61558
Isolation testing:	

Title:	**RD-15 65W L2**	Silanna
P/N:	**RD-15 65W L2**	
Rev: 0.1	Eng:	
	Chk:	Silanna Semiconductor North America
	Date: June 27, 2023	Sheet 1 of 1

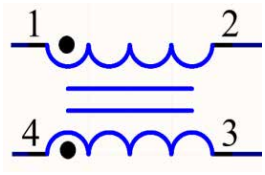
Figure 27. Input EMI CMC (L2) Specification

Input EMI CMC (L3)

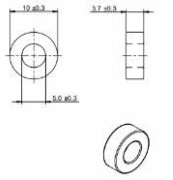
CMC Specification



Pinout



Electrical



Core Dimension

Winding Specification:

Winding	1	2
Material*	AWG26	TIW 0.45mm
Turns	6	6
Parallel wires	1	1
Start Pin	1*	4*
End Pin	2	3
	CMC-Line	CMC-Neutral

Impedance Curve:

Electrical Test Parameter:

INDUCTANCE @ 10kHz/0.1VAC
L(1-2) =150uH ±15%
L(3-4) =150uH ±15%
INDUCTANCE @ 10kHz/0.1VAC
LL(1-2) = 300nH MAX (3-4 shorted)

TURNS RATIO/POLARITY

APPLY: 1.00V @ 10kHz TO PINS (1-3)

Pin: (2-4) = 1V ±3%

DC RESISTANCE OHMS (Ω) @ 25°C
DCR: (1-3) = 0.02Ω MAX

DCR: (2-4) = 0.02Ω MAX

Material List

Material	*Specification*	*Manufacturer*	*Mfr. Part Number*
Core	6.30 × 3.80 × 2.50 mm dimension (T38 - 2.530u)	Würth Elektronik	74270161
AWG26	Magnet wire, dual insulation layer		
TIW 0.45mm	Triple Insulated Wire 0.37mm		

Notes:

All materials need to be min 130 °C, UL certified

Assembly:	
Glue / Varnish:	Not applicable for prototypes
Applicable Standard:	EN 61558
Isolation testing:	

Title:	**RD-15 65W L3**	Silanna
P/N:	**RD-15 65W L3**	Silanna Semiconductor North America
Rev. 0.1	Eng:	
	Chk:	
	Date: June 27, 2023	Sheet 1 of 1

Figure 28. Input EMI CMC (L3) Specification

Performance Data

End-to-End Efficiency

Master USB-C Port (C1)

115 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_C1} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	82.97%	81.12%
75	82.44%	
50	81.33%	
25	77.75%	

V_{OUT_C1} / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	87.93%	85.92%
75	87.65%	
50	86.34%	
25	81.77%	

V_{OUT_C1} / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	89.50%	87.57%
75	89.45%	
50	88.16%	
25	83.19%	

V_{OUT_C1} / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.43%	89.11%
75	90.55%	
50	89.79%	
25	85.67%	

V_{OUT_C1} / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.69%	90.72%
75	91.53%	
50	91.49%	
25	89.18%	

230 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_C1} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	80.46%	78.86%
75	80.08%	
50	78.80%	
25	76.12%	

V_{OUT_C1} / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	86.64%	83.61%
75	85.62%	
50	83.46%	
25	78.71%	

V_{OUT_C1} / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	88.60%	85.84%
75	88.12%	
50	85.97%	
25	80.64%	

V_{OUT_C1} / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.17%	87.69%
75	89.41%	
50	87.89%	
25	83.29%	

V_{OUT_C1} / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency (%)	Average Efficiency
100	91.48%	89.98%
75	91.46%	
50	90.41%	
25	86.56%	

Full Load Efficiency at 90 Vac/115 Vac/230 Vac/265 Vac (measured after USB connector, before cable)

V_{OUT_C1} = 5 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	83.12%
115 Vac @ 60 Hz	3 A	82.97%
230 Vac @ 50 Hz	3 A	80.46%
265 Vac @ 50Hz	3 A	79.44%

V_{OUT_C1} = 9 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	87.67%
115 Vac @ 60 Hz	3 A	87.93%
230 Vac @ 50 Hz	3 A	86.64%
265 Vac @ 50Hz	3 A	85.79%

V_{OUT_C1} = 12 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	88.99%
115 Vac @ 60 Hz	3 A	89.50%
230 Vac @ 50 Hz	3 A	88.60%
265 Vac @ 50Hz	3 A	87.81%

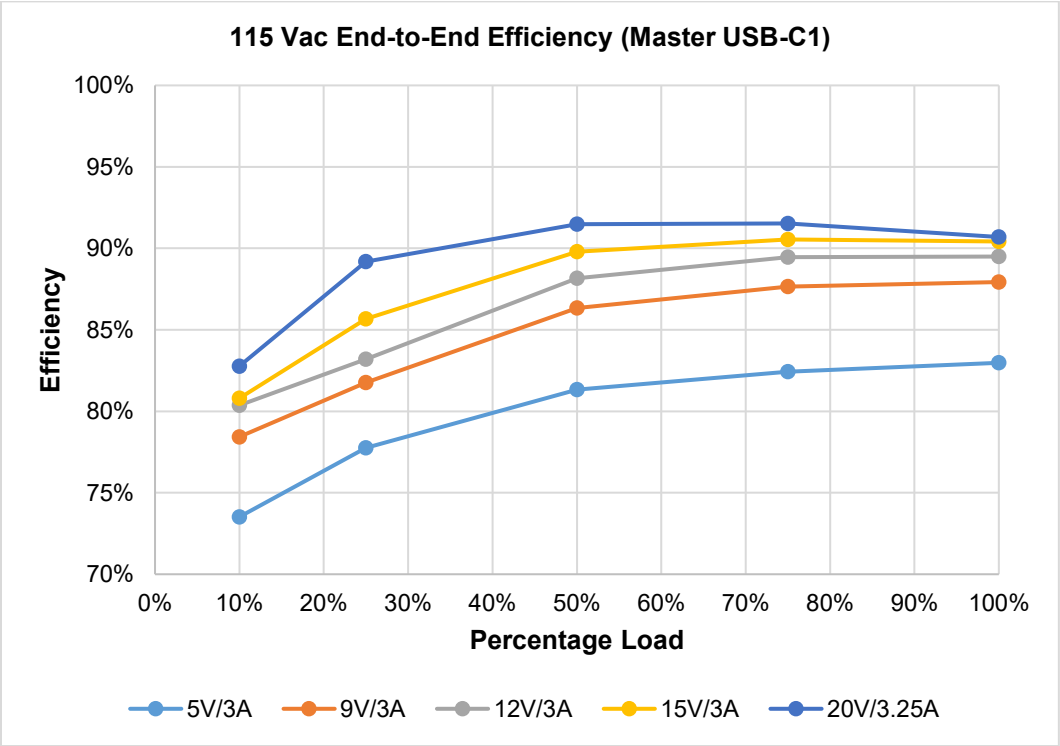
V_{OUT_C1} = 15 V

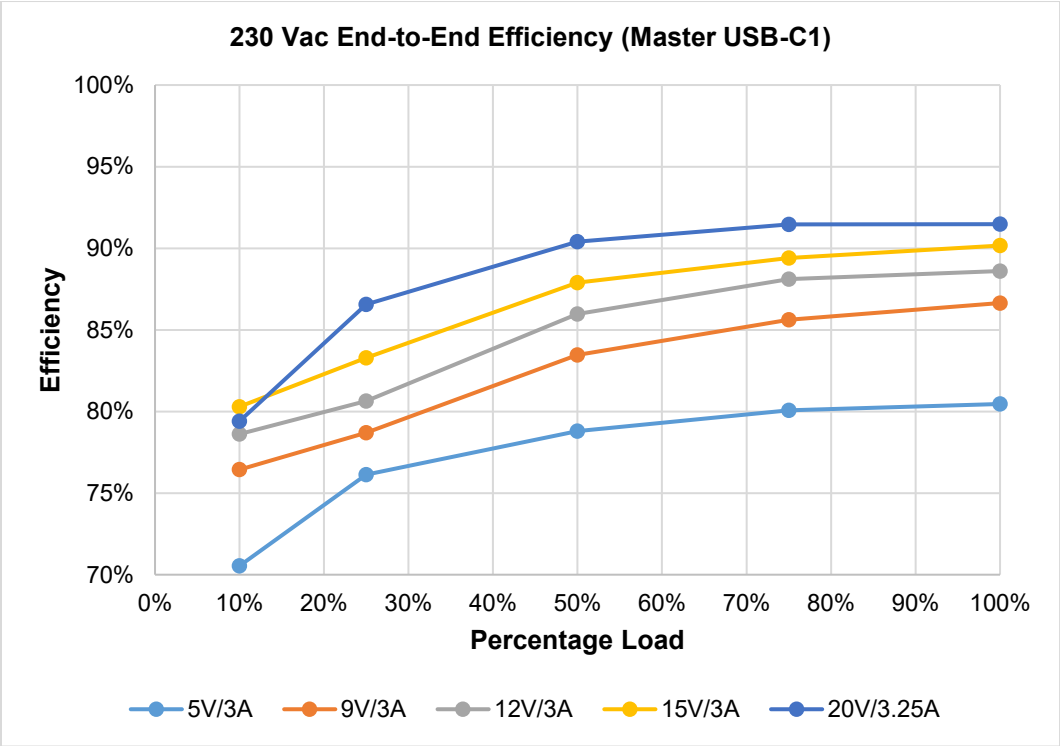
Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	89.57%
115 Vac @ 60 Hz	3 A	90.43%
230 Vac @ 50 Hz	3 A	90.17%
265 Vac @ 50Hz	3 A	89.57%

V_{OUT_C1} = 20 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3.25 A	89.22%
115 Vac @ 60 Hz	3.25 A	90.69%
230 Vac @ 50 Hz	3.25 A	91.48%
265 Vac @ 50Hz	3.25 A	91.14%

Master USB-C Port Efficiency Curves





Slave USB-C Port (C2)

115 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_C2} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	82.80%	80.94%
75	82.23%	
50	81.17%	
25	77.54%	

V_{OUT_C2} / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	87.80%	85.97%
75	87.54%	
50	86.21%	
25	82.34%	

V_{OUT_C2} / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	89.39%	87.76%
75	89.35%	
50	88.06%	
25	84.26%	

V_{OUT_C2} / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.35%	89.03%
75	90.46%	
50	89.73%	
25	85.60%	

V_{OUT_C2} / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.65%	90.69%
75	91.47%	
50	91.48%	
25	89.16%	

230 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_C2} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	80.26%	78.69%
75	79.92%	
50	78.65%	
25	75.95%	

V_{OUT_C2} / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	86.53%	83.68%
75	85.53%	
50	83.39%	
25	79.29%	

V_{OUT_C2} / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	88.52%	86.08%
75	88.03%	
50	85.90%	
25	81.87%	

V_{OUT_C2} / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	90.11%	87.64%
75	89.36%	
50	87.85%	
25	83.24%	

V_{OUT_C2} / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency (%)	Average Efficiency
100	91.42%	89.94%
75	91.42%	
50	90.39%	
25	86.54%	

Full Load Efficiency at 90 Vac/115 Vac/230 Vac/265 Vac (measured after USB connector, before cable)

V_{OUT_C2} = 5 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	82.88%
115 Vac @ 60 Hz	3 A	82.80%
230 Vac @ 50 Hz	3 A	80.26%
265 Vac @ 50Hz	3 A	79.27%

V_{OUT_C2} = 9 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	87.53%
115 Vac @ 60 Hz	3 A	87.80%
230 Vac @ 50 Hz	3.A	86.53%
265 Vac @ 50Hz	3 A	85.70%

V_{OUT_C2} = 12 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	88.91%
115 Vac @ 60 Hz	3 A	89.39%
230 Vac @ 50 Hz	3.A	88.52%
265 Vac @ 50Hz	3 A	87.73%

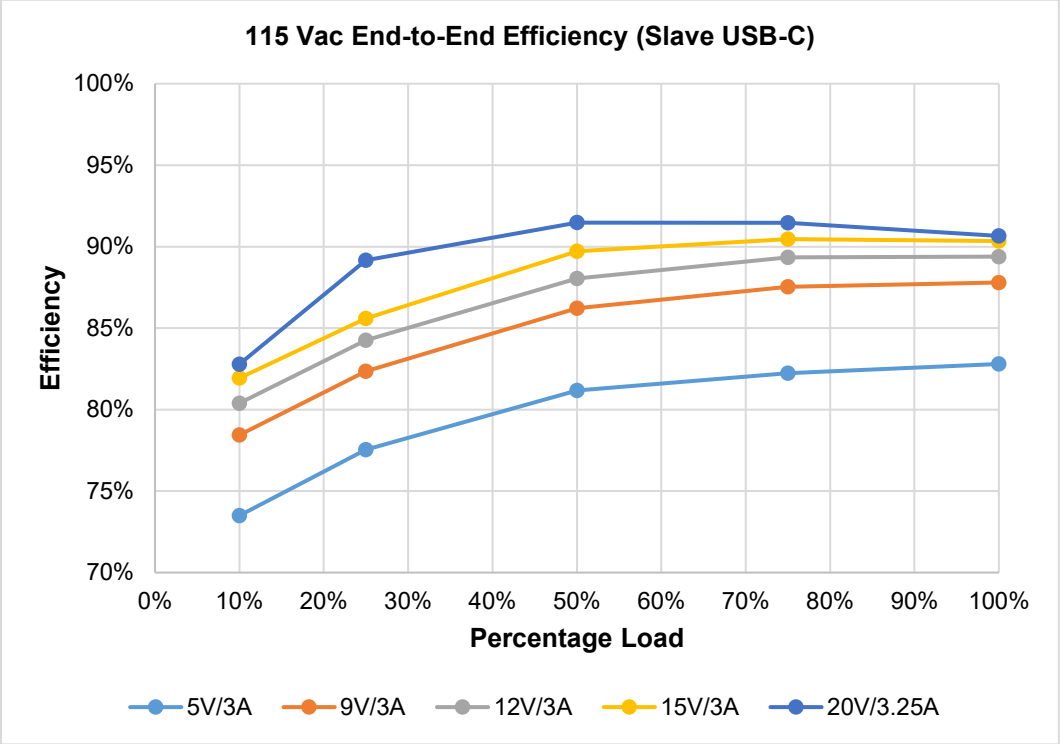
V_{OUT_C2} = 15 V

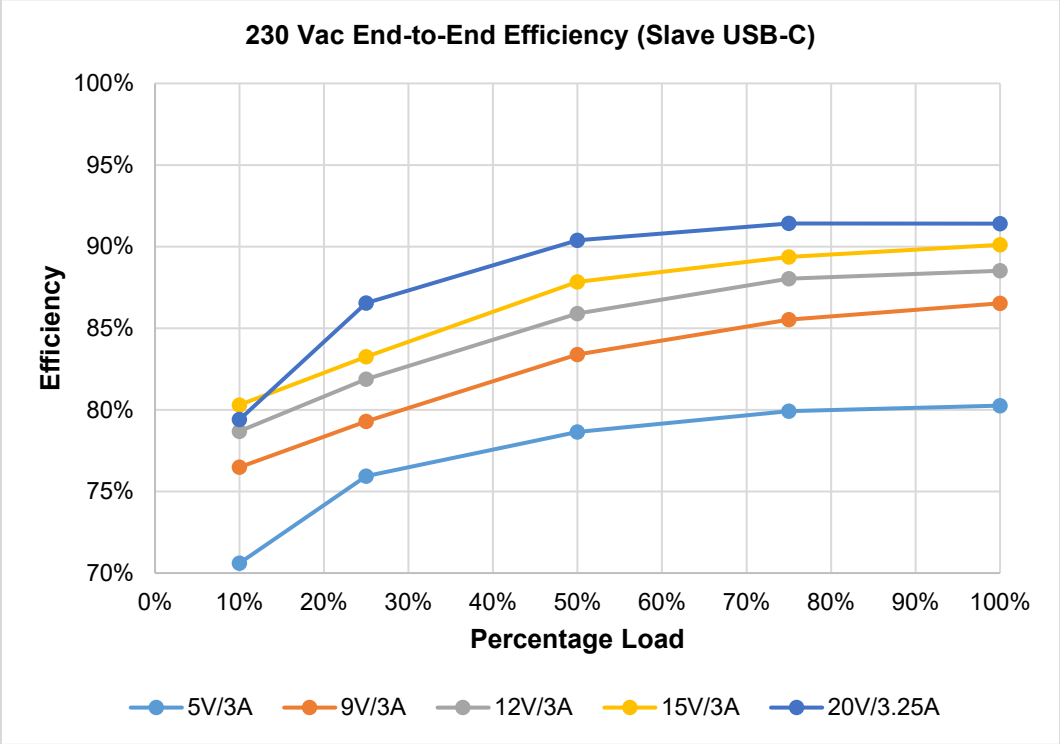
Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	89.54%
115 Vac @ 60 Hz	3 A	90.35%
230 Vac @ 50 Hz	3.A	90.11%
265 Vac @ 50Hz	3 A	89.53%

V_{OUT_C2} = 20 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3.25 A	89.24%
115 Vac @ 60 Hz	3.25 A	90.65%
230 Vac @ 50 Hz	3.25 A	91.42%
265 Vac @ 50Hz	3.25 A	91.11%

Slave USB-C Port Efficiency Curves





Slave USB-A Port (A1)

115 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_A1} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	81.89%	80.53%
75	81.63%	
50	80.93%	
25	77.69%	

V_{OUT_A1} / I_{LOAD_MAX} = 9 V / 2 A

%LOAD	Efficiency (%)	Average Efficiency
100	86.88%	83.97%
75	86.05%	
50	83.14%	
25	79.81%	

V_{OUT_A1} / I_{LOAD_MAX} = 12 V / 1.5 A

%LOAD	Efficiency (%)	Average Efficiency
100	87.89%	84.74%
75	86.70%	
50	83.72%	
25	80.63%	

230 Vac 4-point Average Efficiency (measured after USB Connector and before USB cable via breakout board)

V_{OUT_A1} / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency (%)	Average Efficiency
100	79.47%	78.35%
75	79.41%	
50	78.40%	
25	76.10%	

V_{OUT_A1} / I_{LOAD_MAX} = 9 V / 2 A

%LOAD	Efficiency (%)	Average Efficiency
100	84.81%	82.02%
75	83.27%	
50	80.90%	
25	79.08%	

V_{OUT_A1} / I_{LOAD_MAX} = 12 V / 1.5 A

%LOAD	Efficiency (%)	Average Efficiency
100	85.78%	82.68%
75	83.88%	
50	81.21%	
25	79.85%	

Full Load Efficiency at 90 Vac/115 Vac/230 Vac/265 Vac (measured after USB connector, before cable)

V_{OUT_A1} = 5 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	81.93%
115 Vac @ 60 Hz	3 A	81.89%
230 Vac @ 50 Hz	3 A	79.47%
265 Vac @ 50Hz	3 A	78.53%

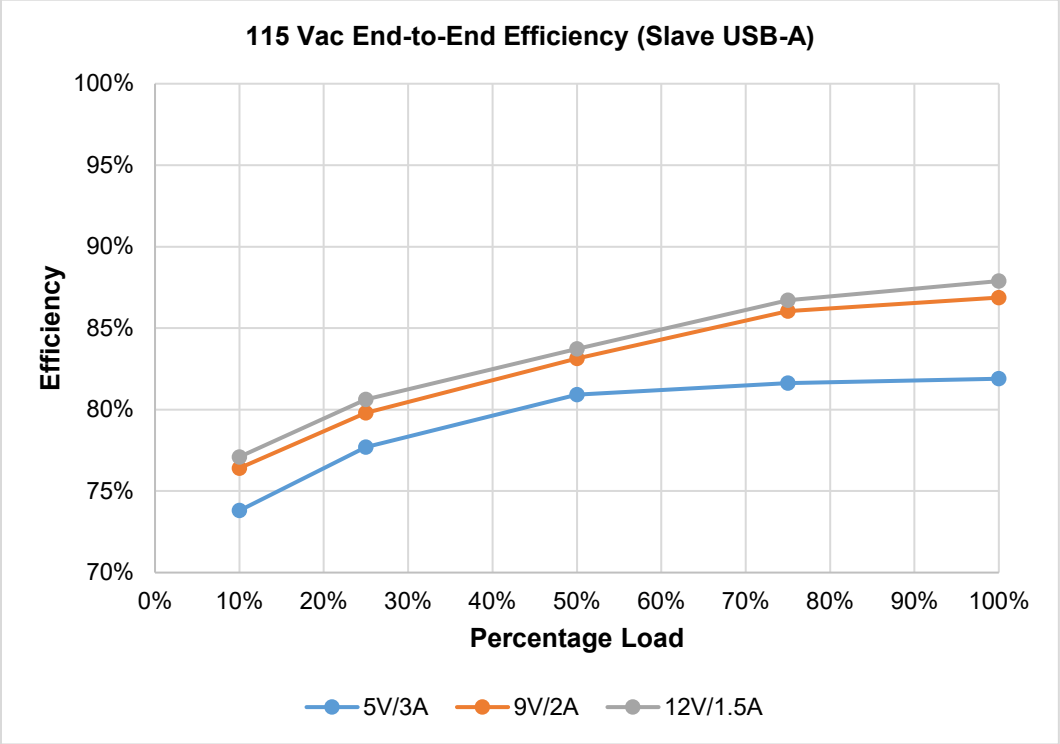
V_{OUT_A1} = 9 V

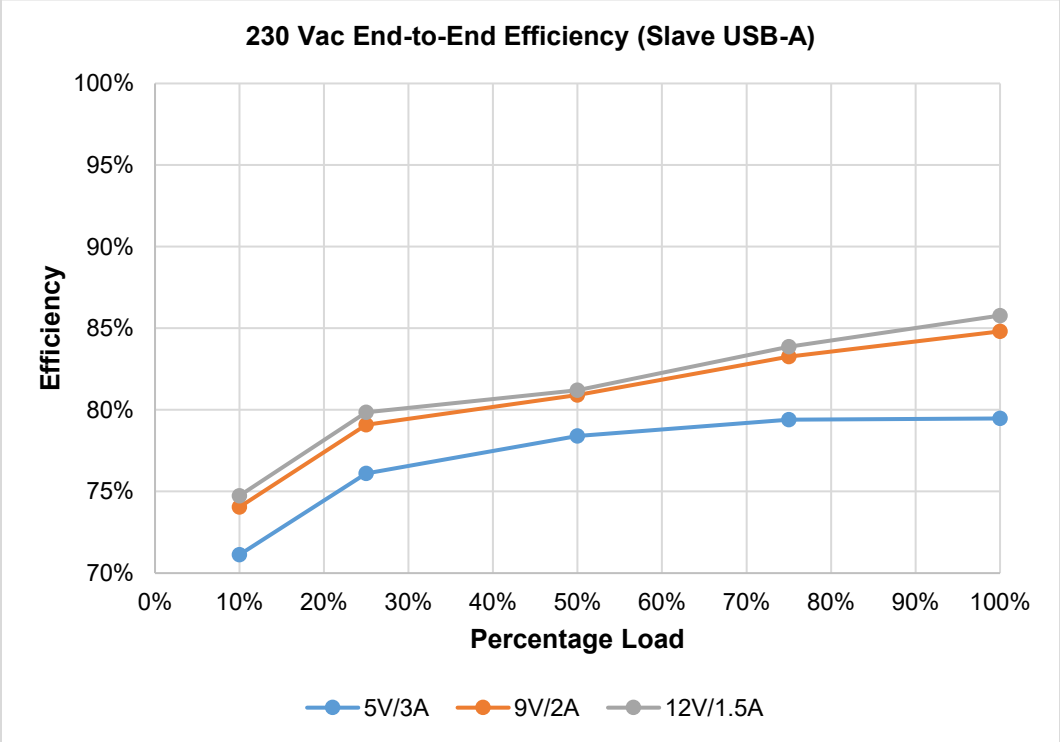
Vin	Iout	Efficiency
90Vac @ 60Hz	2 A	87.05%
115 Vac @ 60 Hz	2 A	86.88%
230 Vac @ 50 Hz	2 A	84.81%
265 Vac @ 50Hz	2 A	83.74%

V_{OUT_A1} = 12 V

Vin	Iout	Efficiency
90Vac @ 60Hz	1.5 A	88.06%
115 Vac @ 60 Hz	1.5 A	87.89%
230 Vac @ 50 Hz	1.5 A	85.78%
265 Vac @ 50Hz	1.5 A	84.70%

Slave USB-A Port Efficiency Curves





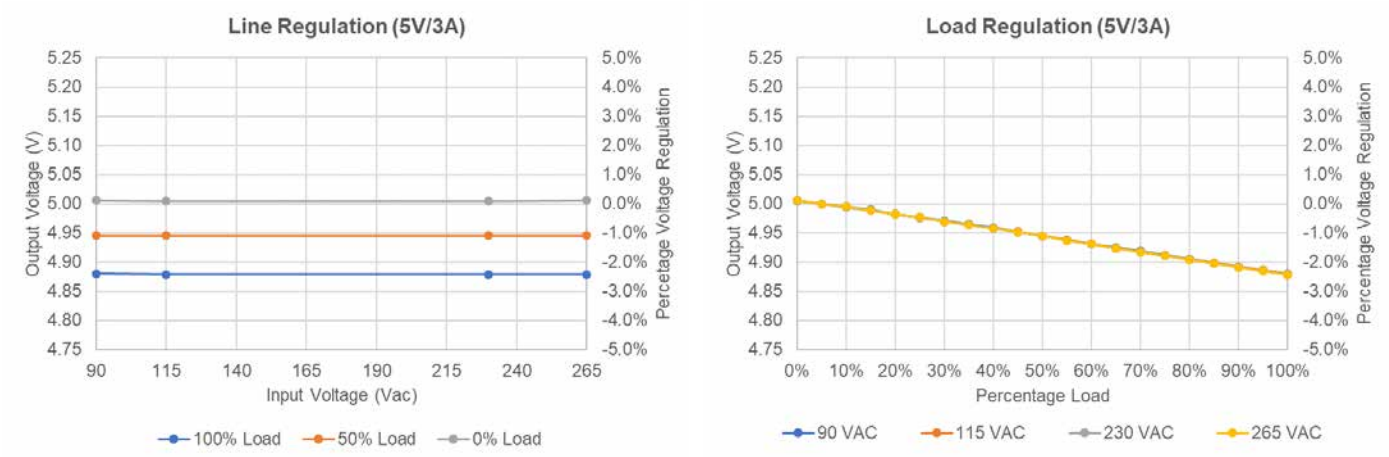
No Load Input Power

Measurements were taken with no USB cable connected across the USB ports. The unit under test was soaked and monitored for five minutes.

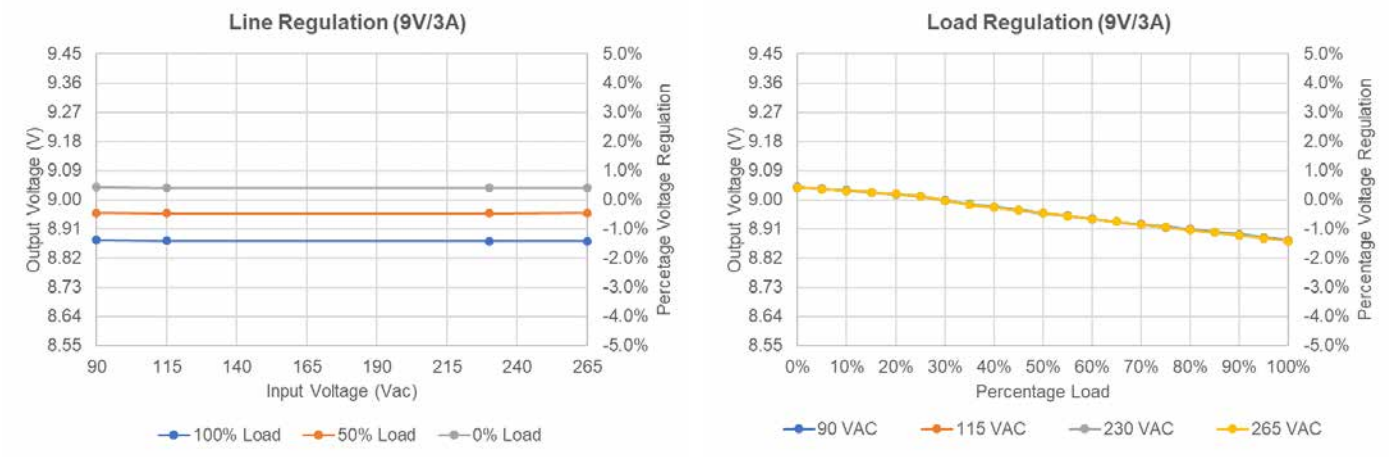
Input Voltage (Vac)	No-Load Power (mW)
90	114.1
115	119.0
230	165.2
265	189.1

Line and Load Output Voltage Regulation

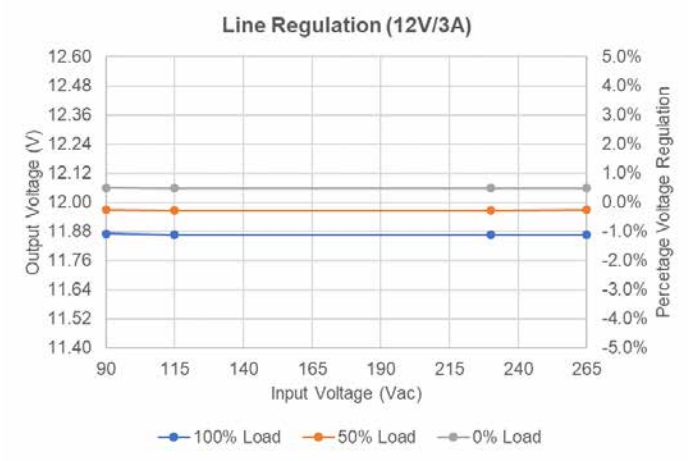
Measurements were taken after the USB connector and before the USB cable via breakout board. Output voltage regulation is computed by sweeping the input voltage from 90 Vac to 265 Vac and changing the load across the USB ports from 0% to 100%.

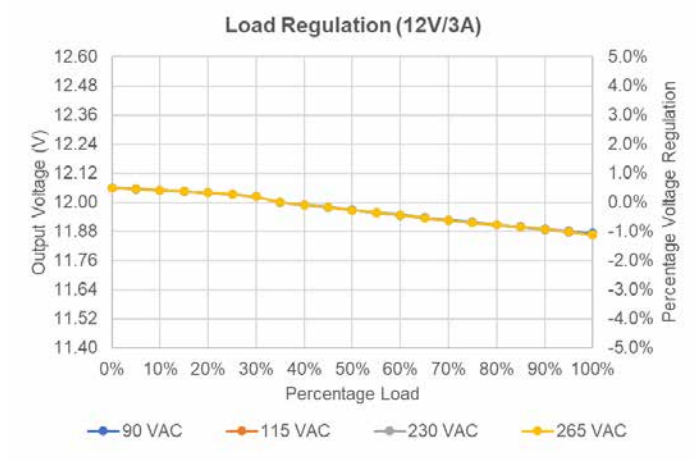


Master USB-C1 Port Line and Load Regulation (5V/3A)

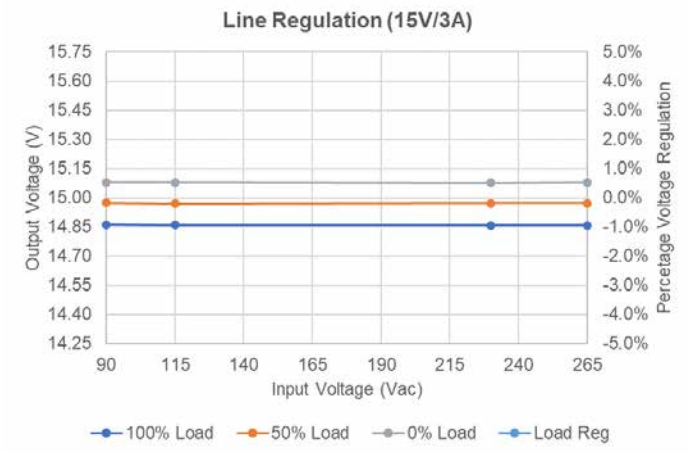


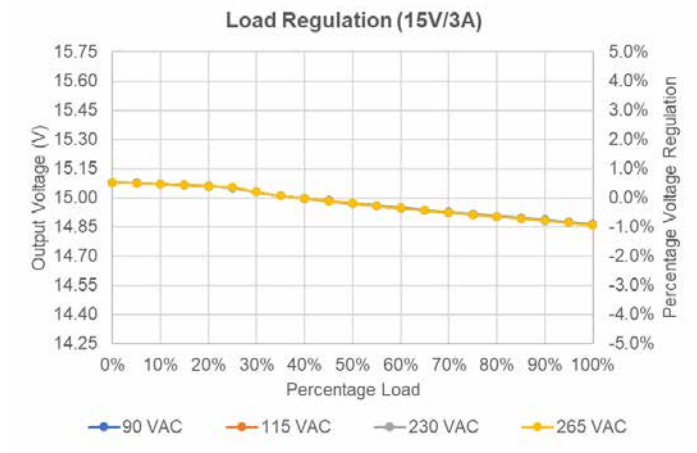
Master USB-C1 Port Line and Load Regulation (9V/3A)



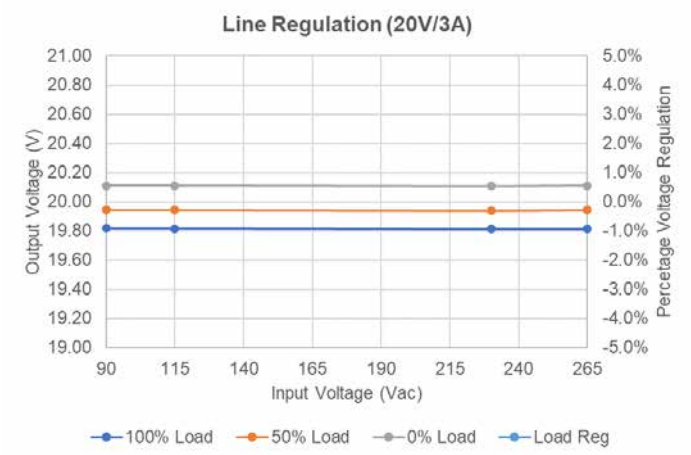


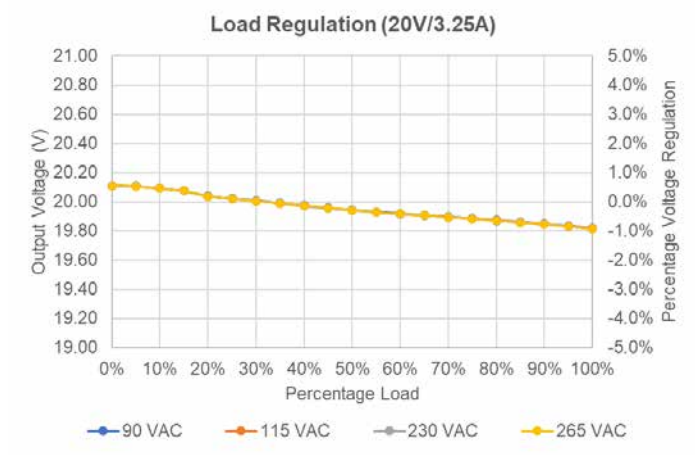
Master USB-C1 Port Line and Load Regulation (12V/3A)



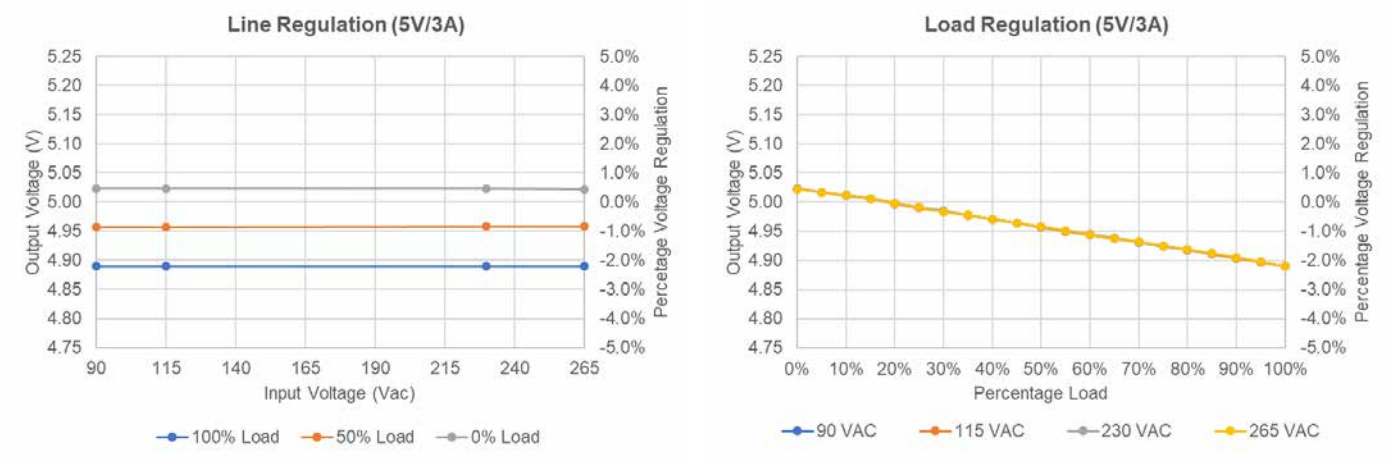


Master USB-C1 Port Line and Load Regulation (15V/3A)

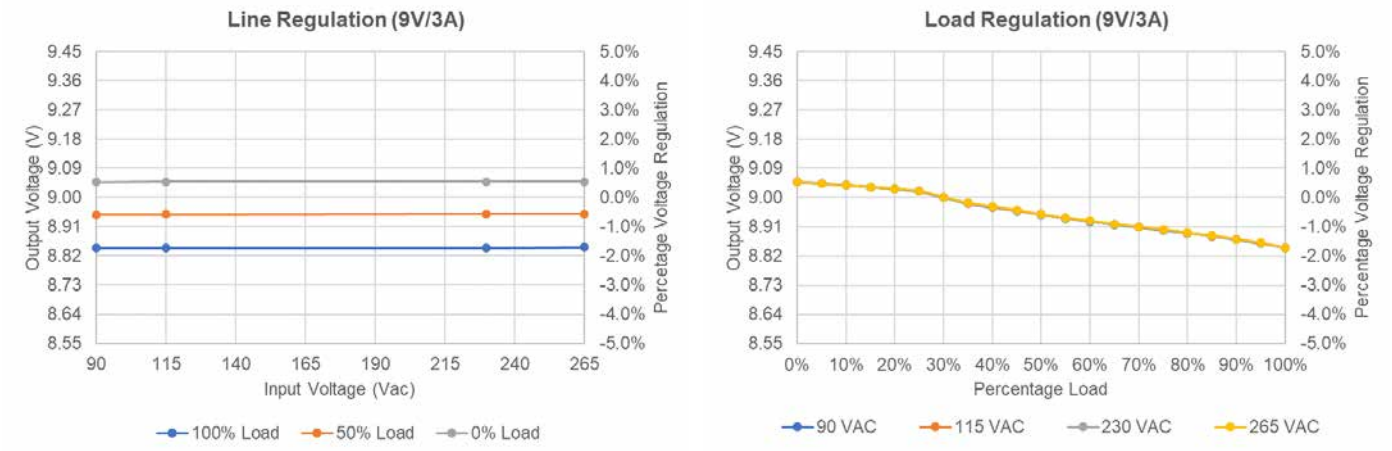




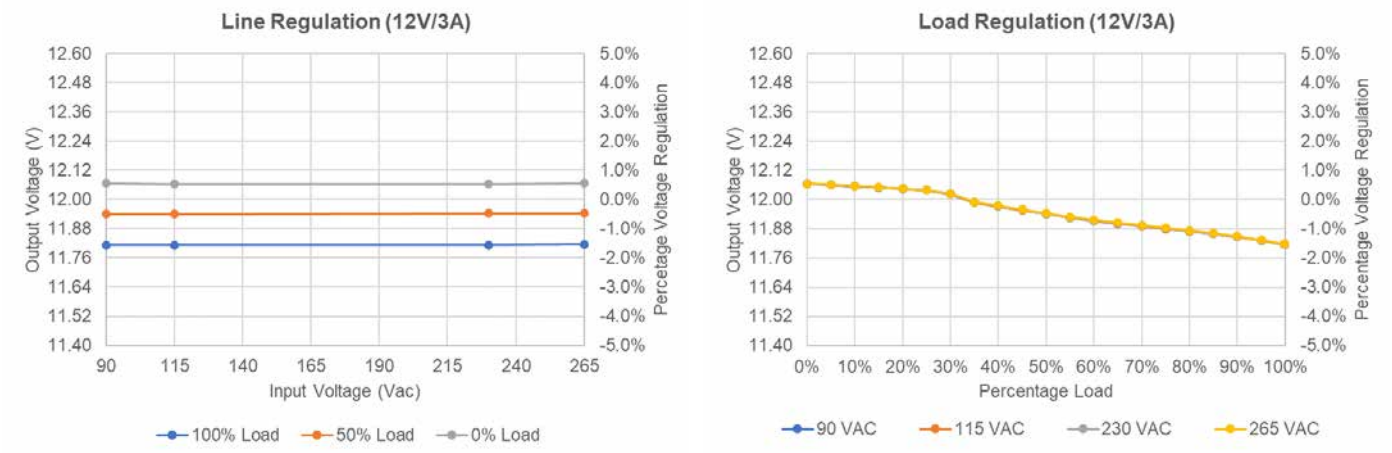
Master USB-C1 Port Line and Load Regulation (20V/3.25A)



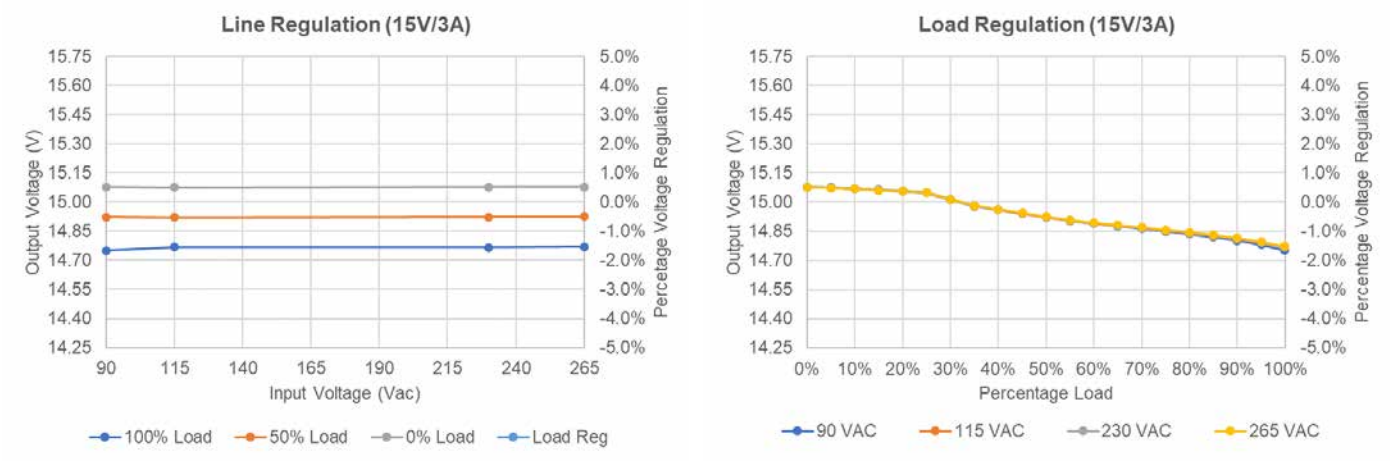
Slave USB-C2 Port Line and Load Regulation (5V/3A)



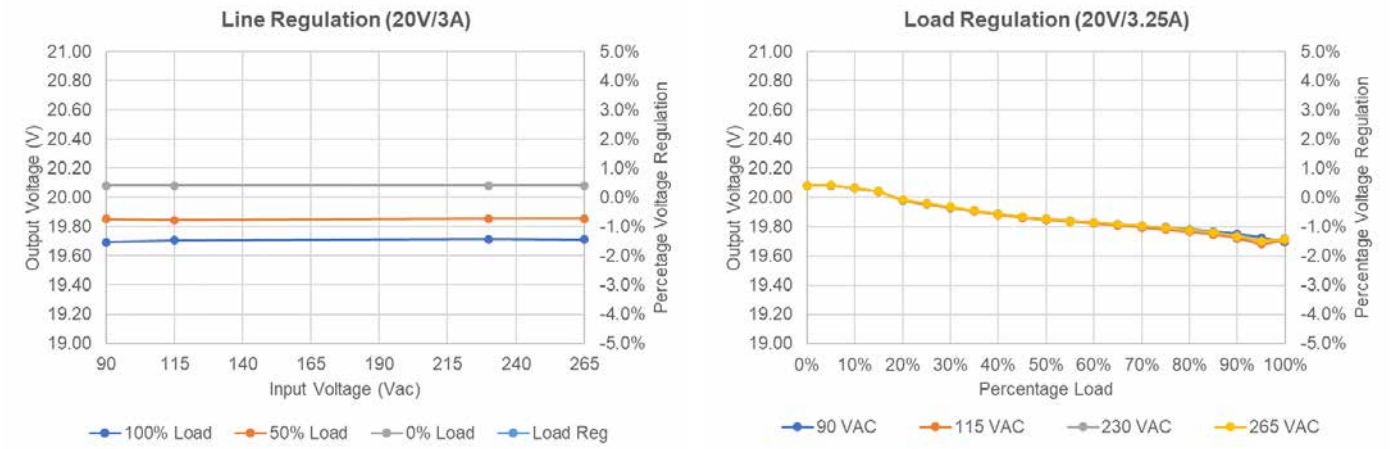
Slave USB-C2 Port Line and Load Regulation (9V/3A)



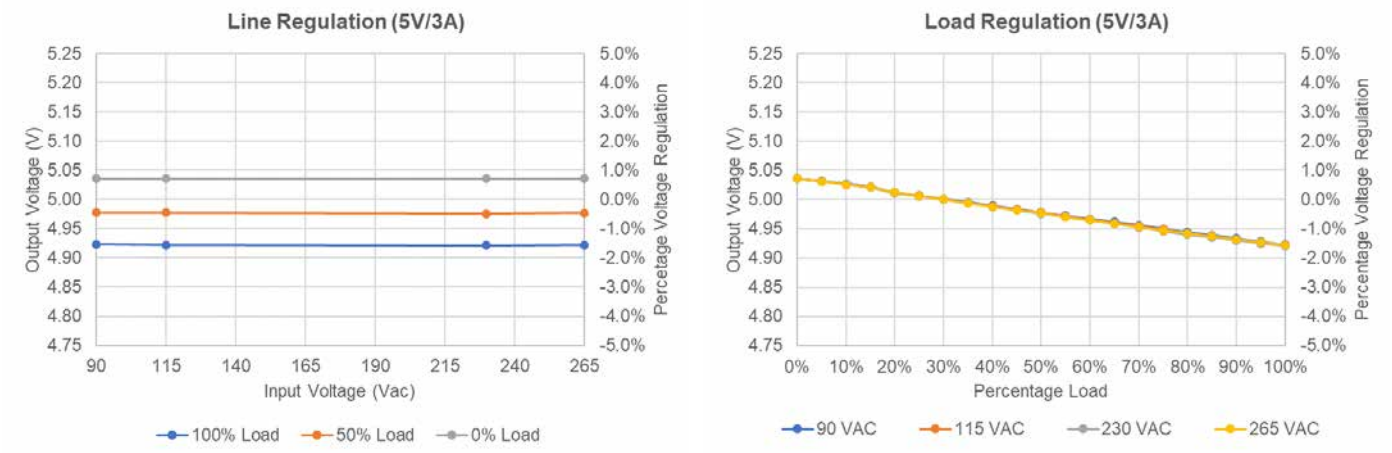
Slave USB-C2 Port Line and Load Regulation (12V/3A)



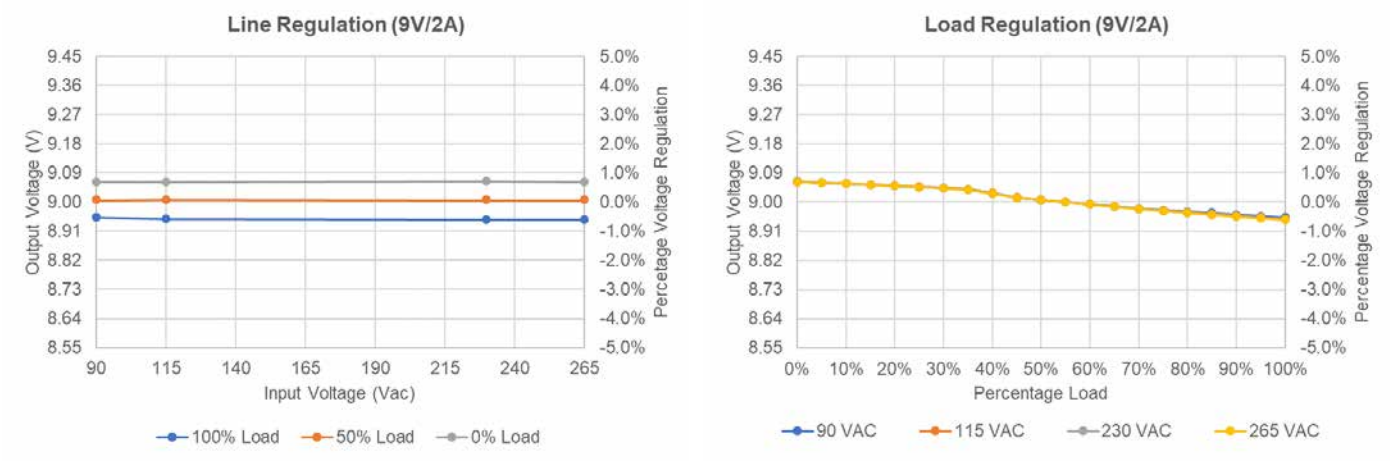
Slave USB-C2 Port Line and Load Regulation (15V/3A)



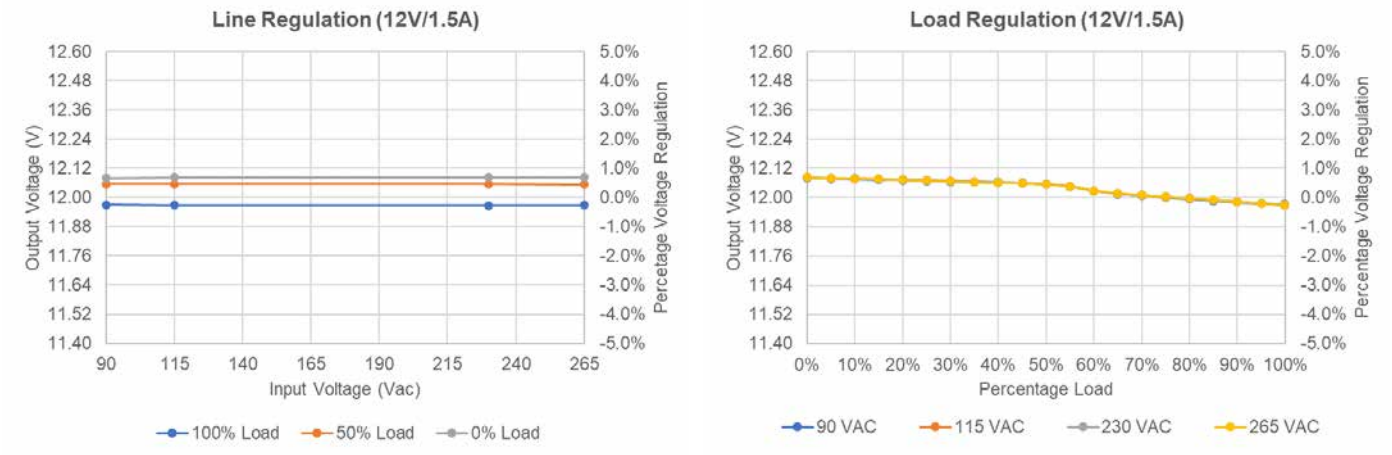
Slave USB-C2 Port Line and Load Regulation (20V/3.25A)



Slave USB-A1 Port Line and Load Regulation (5V/3A)



Slave USB-A1 Port Line and Load Regulation (9V/2A)



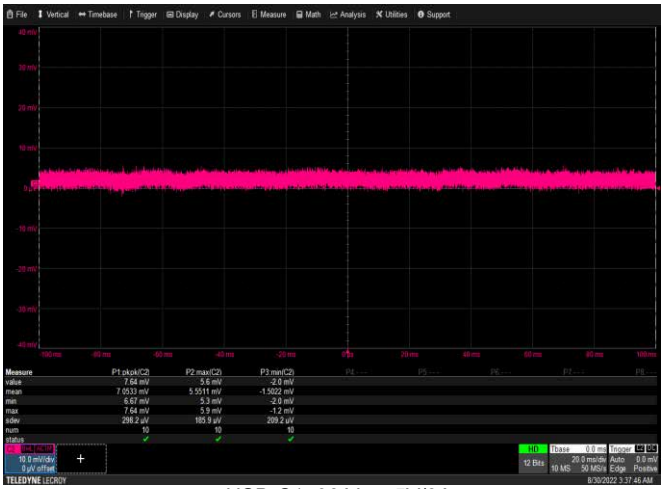
Slave USB-A1 Port Line and Load Regulation (12V/1.5A)

Output Peak-to-Peak Ripple Voltage

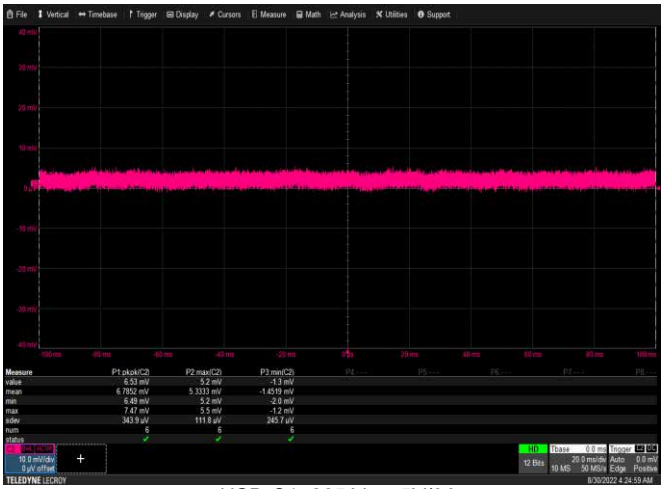
Measurements were taken at the end of the 1.5-meter USB cable with 3x 10 µF 80V electrolytic capacitor and 100 nF ceramic capacitor across the ripple voltage probe.

Input Voltage	Percentage Load	5 V USB-C1	9 V USB-C1	12 V USB-C1	15 V USB-C1	20 V USB-C1
90 Vac	0%	8.3 mV	12.6 mV	15.5 mV	16.8 mV	21.9 mV
	10%	8.5 mV	11.9 mV	15.2 mV	16.8 mV	16.0 mV
	25%	6.8 mV	11.5 mV	15.6 mV	10.3 mV	13.0 mV
	50%	7.6 mV	10.0 mV	12.4 mV	16.3 mV	27.0 mV
	75%	6.6 mV	10.2 mV	14.8 mV	20.4 mV	38.9 mV
	100%	7.6 mV	11.6 mV	19.0 mV	30.9 mV	17.6 mV
265 Vac	0%	9.7 mV	10.8 mV	14.8 mV	17.0 mV	19.6 mV
	10%	8.8 mV	12.0 mV	16.0 mV	17.4 mV	19.2 mV
	25%	8.0 mV	11.0 mV	13.9 mV	11.5 mV	19.2 mV
	50%	7.2 mV	7.6 mV	9.4 mV	13.6 mV	24.5 mV
	75%	7.0 mV	9.6 mV	13.7 mV	21.3 mV	32.1 mV
	100%	7.5 mV	12.9 mV	17.8 mV	27.5 mV	14.5 mV

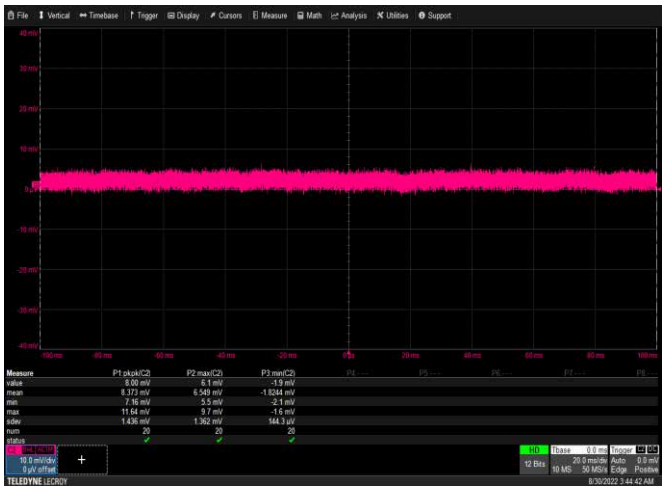
Table 3. Master USB-C1 Port Output Peak-to-Peak Ripple Voltage



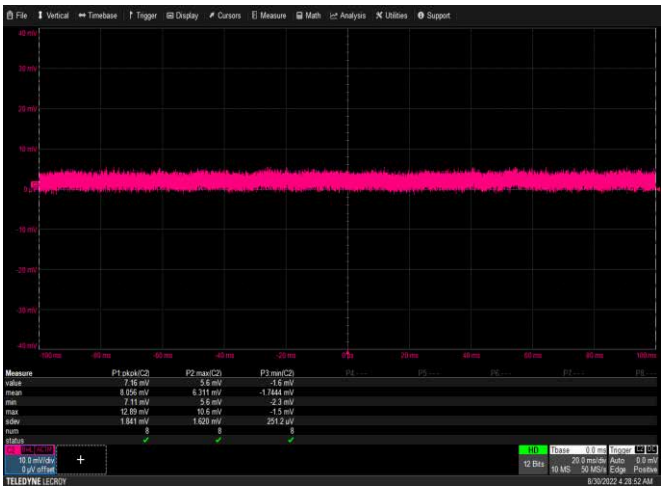
USB-C1: 90 Vac, 5V/3A



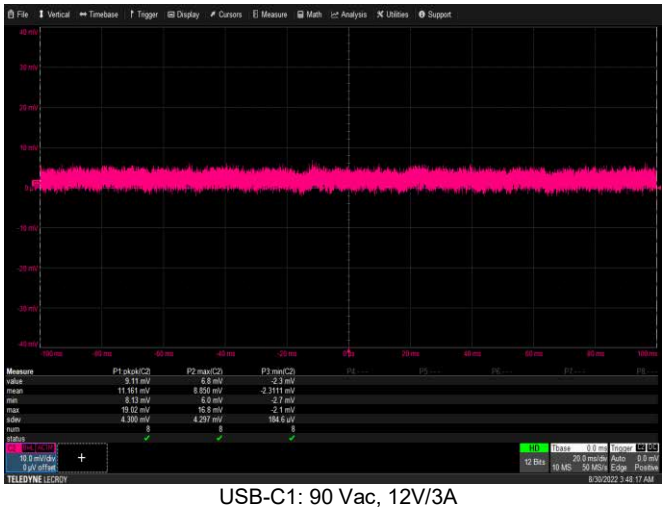
USB-C1: 265 Vac, 5V/3A



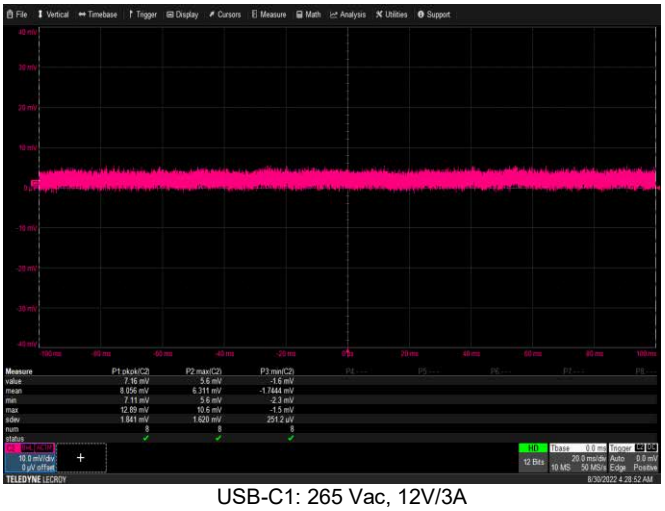
USB-C1: 90 Vac, 9V/3A



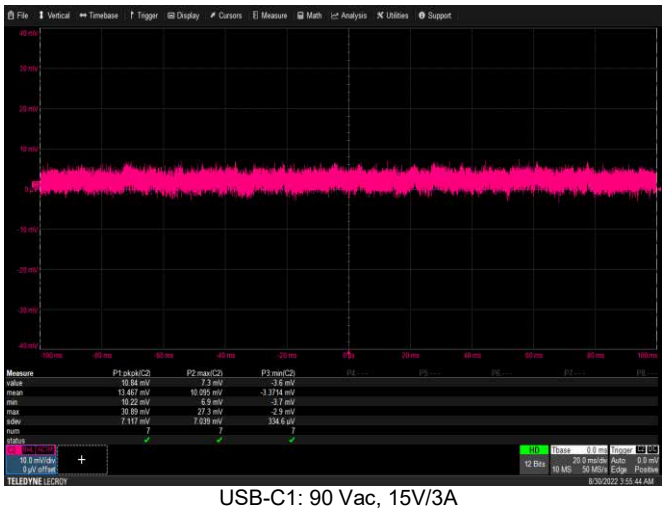
USB-C1: 265 Vac, 9V/3A



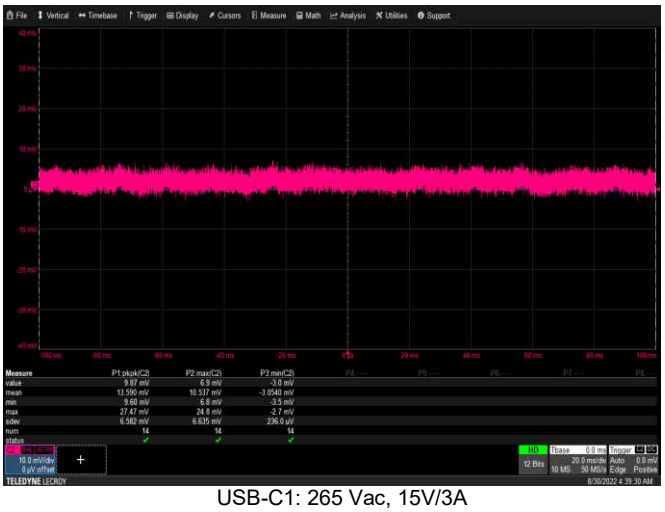
USB-C1: 90 Vac, 12V/3A



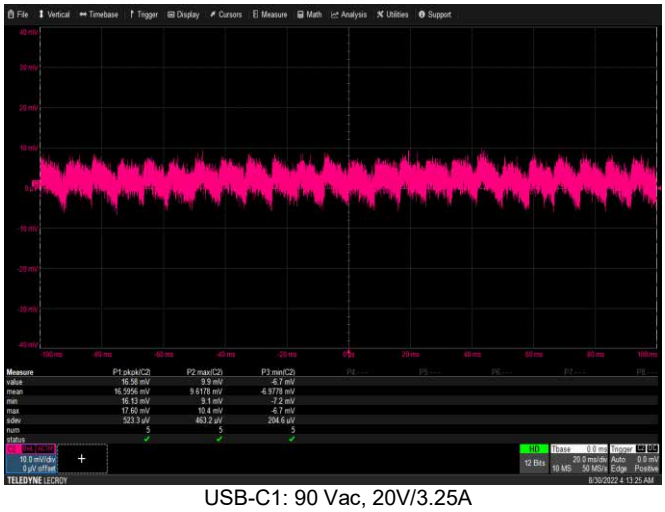
USB-C1: 265 Vac, 12V/3A



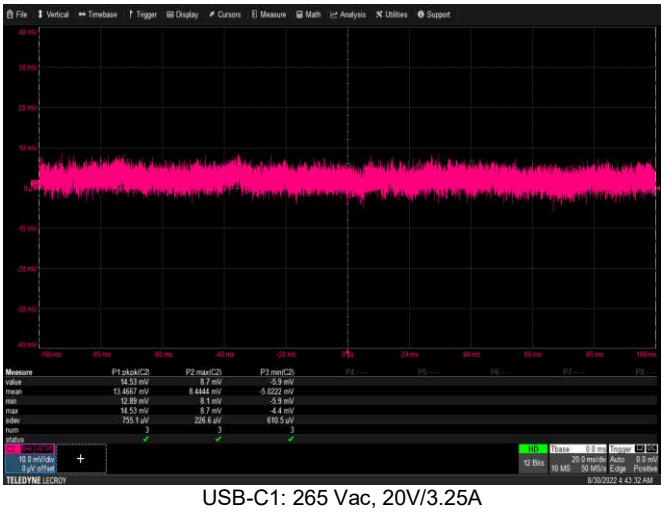
USB-C1: 90 Vac, 15V/3A



USB-C1: 265 Vac, 15V/3A



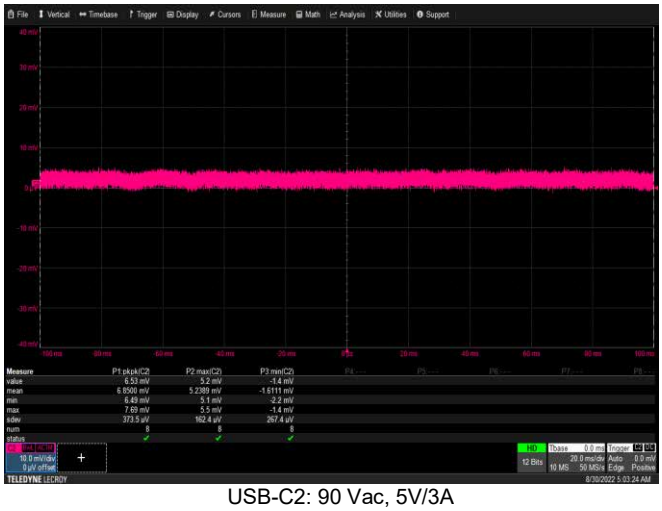
USB-C1: 90 Vac, 20V/3.25A



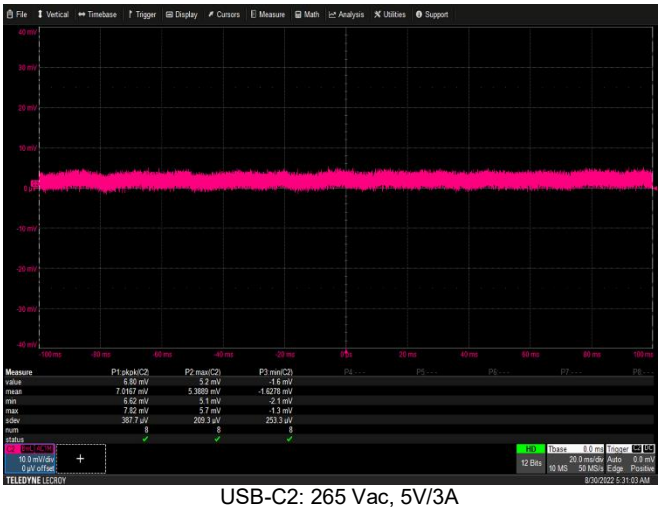
USB-C1: 265 Vac, 20V/3.25A

Input Voltage	Percentage Load	5 V USB-C2	9 V USB-C2	12 V USB-C2	15 V USB-C2	20 V USB-C2
90 Vac	0%	9.2 mV	11.2 mV	14.8 mV	15.1 mV	17.3 mV
	10%	8.8 mV	11.4 mV	14.9 mV	16.6 mV	17.6 mV
	25%	6.7 mV	14.2 mV	17.3 mV	26.8 mV	25.8 mV
	50%	7.6 mV	13.1 mV	17.3 mV	23.7 mV	40.6 mV
	75%	7.7 mV	15.2 mV	22.2 mV	34.6 mV	14.3 mV
	100%	7.7 mV	19.6 mV	30.4 mV	11.4 mV	21.2 mV
265 Vac	0%	10.7 mV	10.3 mV	13.1 mV	15.2 mV	12.3 mV
	10%	9.0 mV	12.0 mV	15.2 mV	16.4 mV	17.6 mV
	25%	7.2 mV	14.8 mV	18.7 mV	27.1 mV	12.8 mV
	50%	7.4 mV	11.3 mV	8.8 mV	22.9 mV	13.6 mV
	75%	7.2 mV	16.6 mV	23.0 mV	29.9 mV	14.0 mV
	100%	7.8 mV	21.1 mV	27.0 mV	36.6 mV	11.6 mV

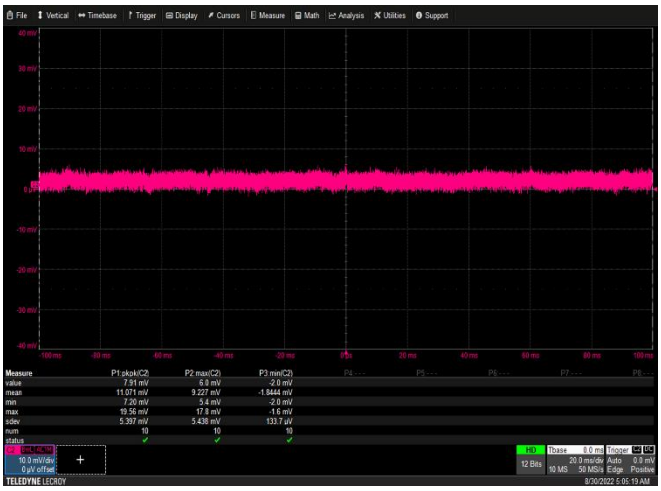
Table 4.Slave USB-C2 Port Output Peak-to-Peak Ripple Voltage



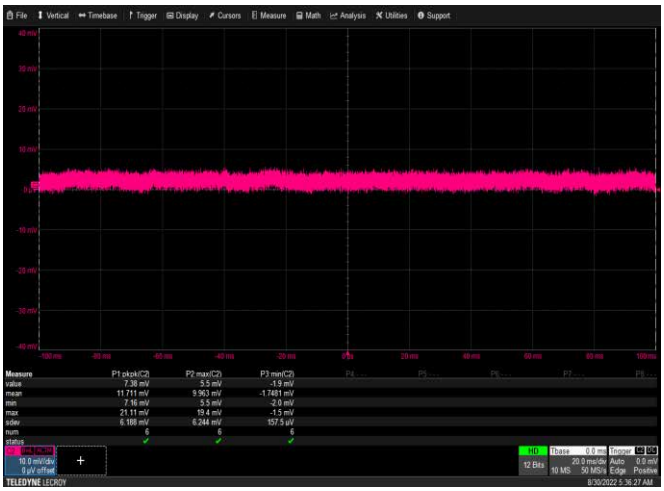
USB-C2: 90 Vac, 5V/3A



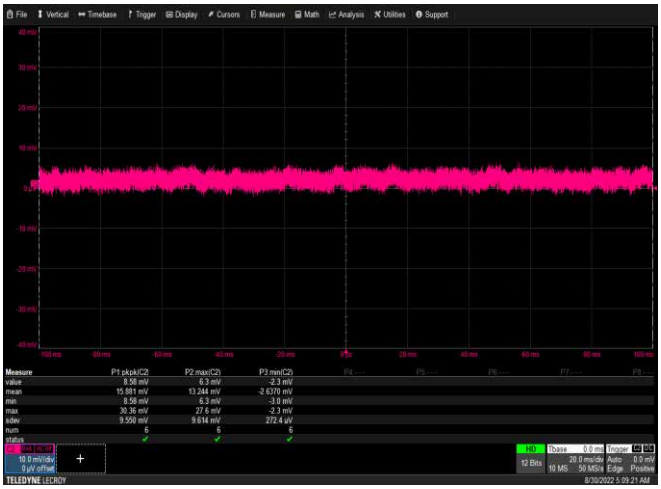
USB-C2: 265 Vac, 5V/3A



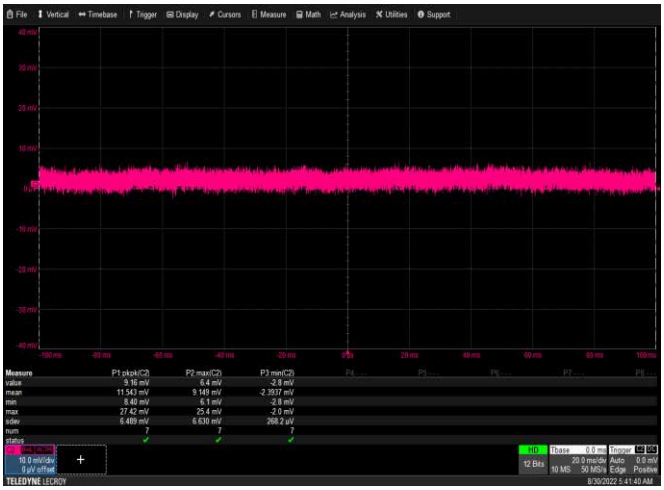
USB-C2: 90 Vac, 9V/3A



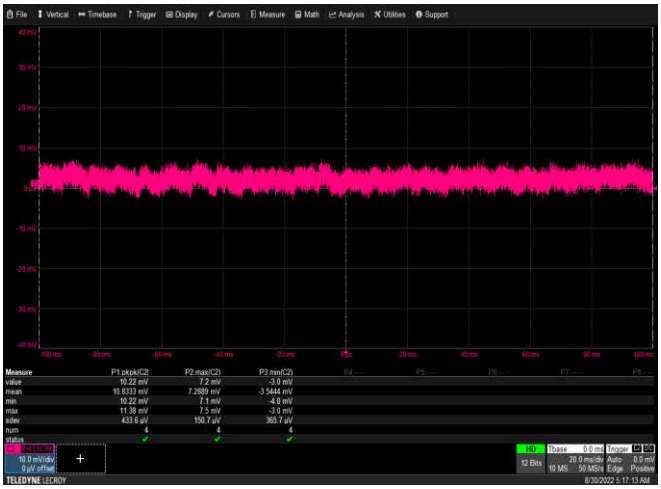
USB-C2: 265 Vac, 9V/3A



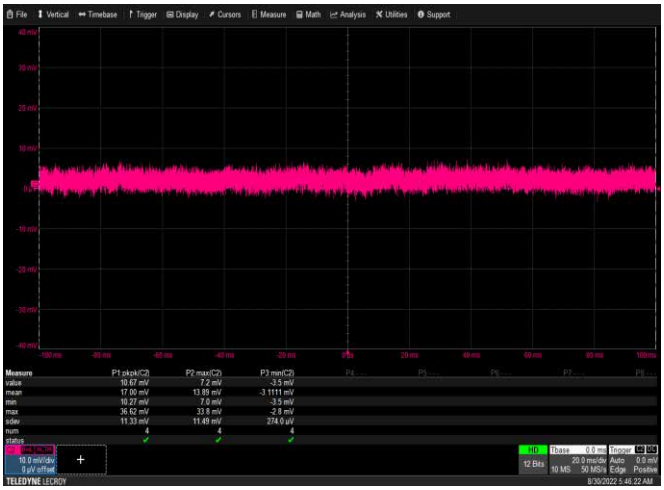
USB-C2: 90 Vac, 12V/3A



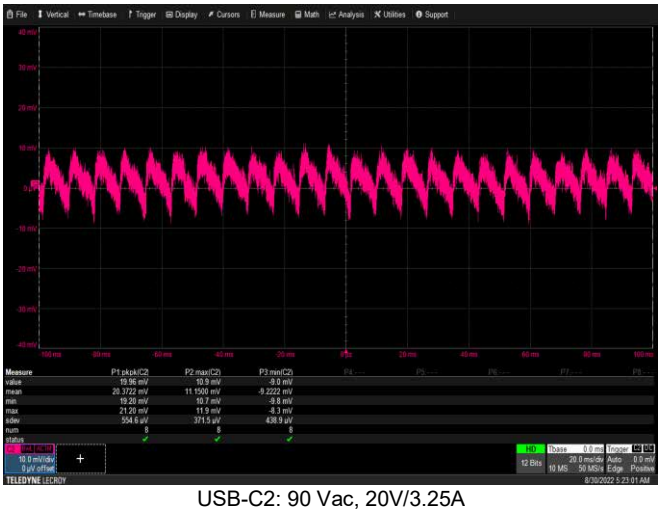
USB-C2: 265 Vac, 12V/3A



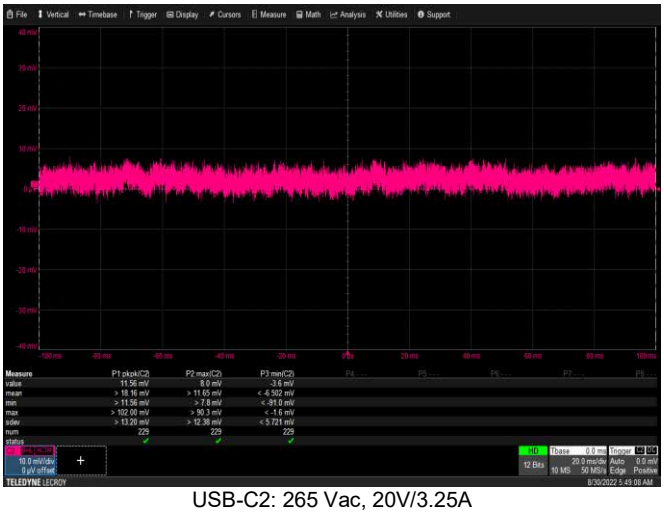
USB-C2: 90 Vac, 15V/3A



USB-C2: 265 Vac, 15V/3A



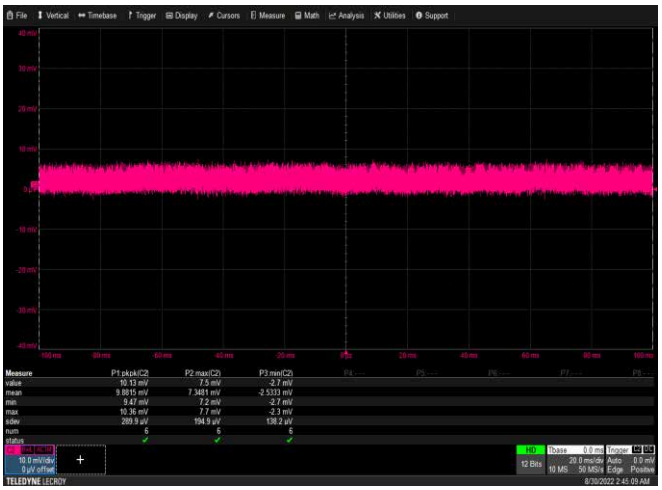
USB-C2: 90 Vac, 20V/3.25A



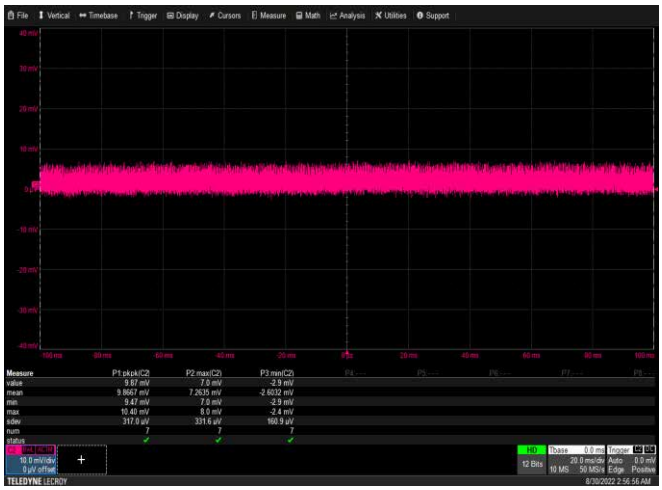
USB-C2: 265 Vac, 20V/3.25A

Input Voltage	Percentage Load	5 V USB-A1	9 V USB-A1	12 V USB-A1
90 Vac	0%	13.5 mV	13.4 mV	16.7 mV
	10%	16.4 mV	32.6 mV	85.4 mV
	25%	9.3 mV	17.2 mV	19.0 mV
	50%	9.6 mV	10.0 mV	19.0 mV
	75%	9.2 mV	10.8 mV	11.4 mV
	100%	10.1 mV	14.3 mV	17.6 mV
265 Vac	0%	17.1 mV	13.9 mV	18.3 mV
	10%	17.1 mV	38.8 mV	84.3 mV
	25%	9.5 mV	17.7 mV	21.7 mV
	50%	9.6 mV	10.1 mV	19.4 mV
	75%	9.9 mV	9.9 mV	10.7 mV
	100%	9.9 mV	17.2 mV	10.8 mV

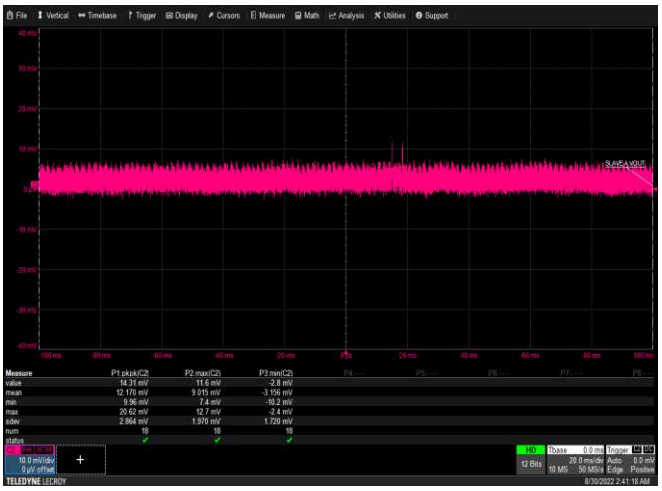
Table 5. Slave USB-A1 Port Output Peak-to-Peak Ripple Voltage



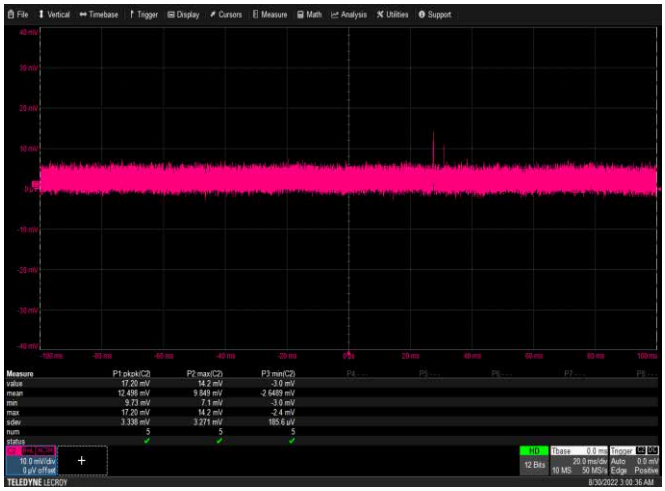
USB-A1: 90 Vac, 5V/3A



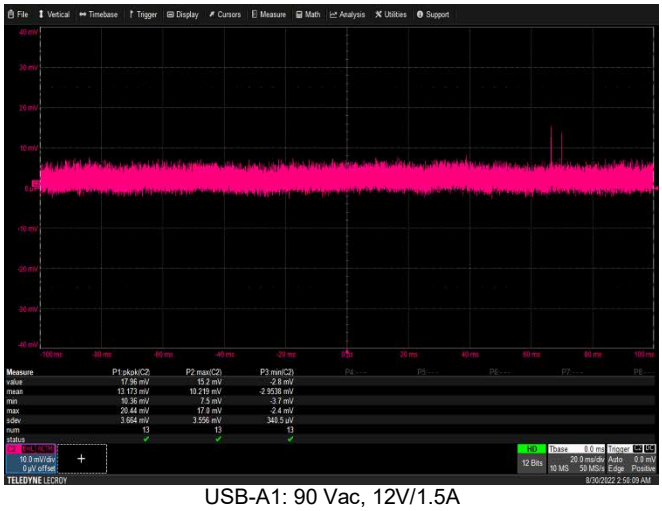
USB-A1: 265 Vac, 5V/3A



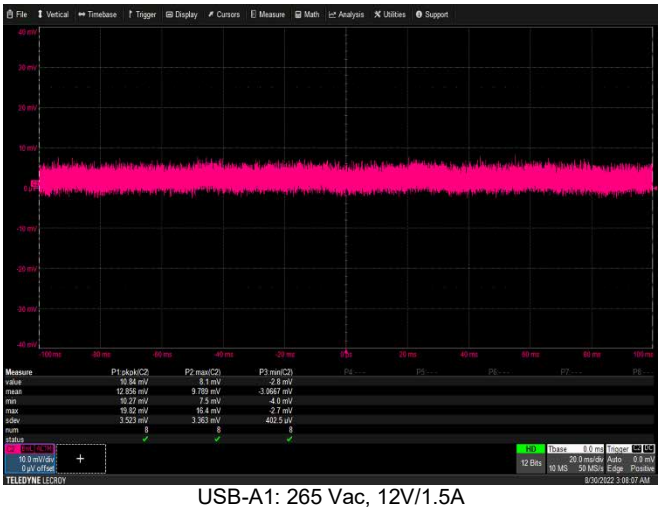
USB-A1: 90 Vac, 9V/2A



USB-A1: 265 Vac, 9V/2A



USB-A1: 90 Vac, 12V/1.5A



USB-A1: 265 Vac, 12V/1.5A

Output Load Transient (Dynamic Loading)

Measurements are taken at the end of the USB connector and before the USB cable via a breakout board. Dynamic loading was applied across each USB ports while monitoring the overshoot and undershoot on the output voltage during each load transient conditions.

Output Load Transient	Input Voltage	Output Voltage USB-C1	Measured Overshoot	Overshoot Limit	Measured Undershoot	Undershoot Limit
0% - 50% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.212 V	5.75 V	4.743 V	4.25 V
		9 V	9.211 V	9.95 V	8.696 V	8.05 V
		12 V	12.263 V	13.10 V	11.700 V	10.90 V
		15 V	15.297 V	16.25 V	14.685 V	13.75 V
		20 V	20.238 V	21.50 V	19.703 V	18.50 V
	265 Vac	5 V	5.209 V	5.75 V	4.741 V	4.25 V
		9 V	9.216 V	9.95 V	8.693 V	8.05 V
		12 V	12.259 V	13.10 V	11.700 V	10.90 V
		15 V	15.298 V	16.25 V	14.687 V	13.75 V
		20 V	20.240 V	21.50 V	19.702 V	18.50 V
50% - 100% - 50% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.196 V	5.75 V	4.725 V	4.25 V
		9 V	9.180 V	9.95 V	8.644 V	8.05 V
		12 V	12.202 V	13.10 V	11.654 V	10.90 V
		15 V	15.174 V	16.25 V	14.655 V	13.75 V
		20 V	20.137 V	21.50 V	19.572 V	18.50 V
	265 Vac	5 V	5.190 V	5.75 V	4.719 V	4.25 V
		9 V	9.166 V	9.95 V	8.636 V	8.05 V
		12 V	12.187 V	13.10 V	11.663 V	10.90 V
		15 V	15.179 V	16.25 V	14.655 V	13.75 V
		20 V	20.125 V	21.50 V	19.575 V	18.50 V
0% - 100% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.360 V	5.75 V	4.524 V	4.25 V
		9 V	9.403 V	9.95 V	8.481 V	8.05 V
		12 V	12.405 V	13.10 V	11.429 V	10.90 V
		15 V	15.400 V	16.25 V	14.368 V	13.75 V
		20 V	20.391 V	21.50 V	19.153 V	18.50 V
	265 Vac	5 V	5.358 V	5.75 V	4.523 V	4.25 V
		9 V	9.397 V	9.95 V	8.476 V	8.05 V
		12 V	12.404 V	13.10 V	11.428 V	10.90 V
		15 V	15.401 V	16.25 V	14.369 V	13.75 V
		20 V	20.421 V	21.50 V	19.146 V	18.50 V

Table 6. Master USB-C1 Port Output Overshoot and Undershoot during Load Transients

Output Load Transient	Input Voltage	Output Voltage USB-C2	Measured Overshoot	Overshoot Limit	Measured Undershoot	Undershoot Limit
0% - 50% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.188 V	5.75 V	4.733 V	4.25 V
		9 V	9.222 V	9.95 V	8.721 V	8.05 V
		12 V	12.232 V	13.10 V	11.720 V	10.90 V
		15 V	15.244 V	16.25 V	14.710 V	13.75 V
		20 V	20.216 V	21.50 V	19.693 V	18.50 V
	265 Vac	5 V	5.226 V	5.75 V	4.735 V	4.25 V
		9 V	9.187 V	9.95 V	8.707 V	8.05 V
		12 V	12.227 V	13.10 V	11.709 V	10.90 V
		15 V	15.217 V	16.25 V	14.680 V	13.75 V
		20 V	20.200 V	21.50 V	19.686 V	18.50 V
50% - 100% - 50% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.160 V	5.75 V	4.746 V	4.25 V
		9 V	9.147 V	9.95 V	8.706 V	8.05 V
		12 V	12.128 V	13.10 V	11.679 V	10.90 V
		15 V	15.087 V	16.25 V	14.644 V	13.75 V
		20 V	19.974 V	21.50 V	19.498 V	18.50 V
	265 Vac	5 V	5.172 V	5.75 V	4.744 V	4.25 V
		9 V	9.108 V	9.95 V	8.711 V	8.05 V
		12 V	12.106 V	13.10 V	11.679 V	10.90 V
		15 V	15.099 V	16.25 V	14.659 V	13.75 V
		20 V	19.981 V	21.50 V	19.510 V	18.50 V
0% - 100% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.236 V	5.75 V	4.582 V	4.25 V
		9 V	9.309 V	9.95 V	8.525 V	8.05 V
		12 V	12.353 V	13.10 V	11.494 V	10.90 V
		15 V	15.293 V	16.25 V	14.435 V	13.75 V
		20 V	20.254 V	21.50 V	19.226 V	18.50 V
	265 Vac	5 V	5.379 V	5.75 V	4.569 V	4.25 V
		9 V	9.315 V	9.95 V	8.484 V	8.05 V
		12 V	12.303 V	13.10 V	11.481 V	10.90 V
		15 V	15.283 V	16.25 V	14.428 V	13.75 V
		20 V	20.237 V	21.50 V	19.185 V	18.50 V

Table 7. Slave USB-C2 Port Output Overshoot and Undershoot during Load Transients

Output Load Transient	Input Voltage	Output Voltage USB-C2	Measured Overshoot	Overshoot Limit	Measured Undershoot	Undershoot Limit
0% - 50% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.196 V	5.75 V	4.761 V	4.25 V
		9 V	9.172 V	9.95 V	8.759 V	8.05 V
		12 V	12.294 V	13.10 V	11.753 V	10.90 V
	265 Vac	5 V	5.204 V	5.75 V	4.757 V	4.25 V
		9 V	9.169 V	9.95 V	8.767 V	8.05 V
		12 V	12.290 V	13.10 V	11.758 V	10.90 V
50% - 100% - 50% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.149 V	5.75 V	4.730 V	4.25 V
		9 V	9.117 V	9.95 V	8.798 V	8.05 V
		12 V	12.120 V	13.10 V	11.874 V	10.90 V
	265 Vac	5 V	5.148 V	5.75 V	4.715 V	4.25 V
		9 V	9.126 V	9.95 V	8.782 V	8.05 V
		12 V	12.119 V	13.10 V	11.873 V	10.90 V
0% - 100% - 0% 1 kHz 50% duty cycle 1 A/µs slew rate	90 Vac	5 V	5.339 V	5.75 V	4.544 V	4.25 V
		9 V	9.273 V	9.95 V	8.639 V	8.05 V
		12 V	12.227 V	13.10 V	11.718 V	10.90 V
	265 Vac	5 V	5.339 V	5.75 V	4.544 V	4.25 V
		9 V	9.262 V	9.95 V	8.640 V	8.05 V
		12 V	12.240 V	13.10 V	11.712 V	10.90 V

Table 8. Slave USB-A1 Port Output Overshoot and Undershoot during Load Transients

Brown-In and Brown-Out

AC voltage across the input terminals is slowly increased (brown-in) and decreased (brown-out) at a rate of 1 Vac per second to check the turn-on and turn-off levels, respectively.

- Brown-In (0 Vac to 100 Vac at 1 Vac per second)

USB-C1 Output	0% Load	100% Load
5 V	87.0 Vac	87.2 Vac

CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output

0 Vac to 100 Vac at 1 Vac/second, 5V/0A (USB-C1)

0 Vac to 100 Vac at 1 Vac/second, 5V/3A (USB-C1)

- Brown-Out (100 Vac to 0 Vac at 1 Vac per second)

USB-C1 Output	0% Load	100% Load
5 V	47.5 Vac	52.6 Vac
9 V	42.9 Vac	58.3 Vac
12 V	47.2 Vac	61.9 Vac
15 V	47.5 Vac	65.0 Vac
20 V	42.9 Vac	75.8 Vac

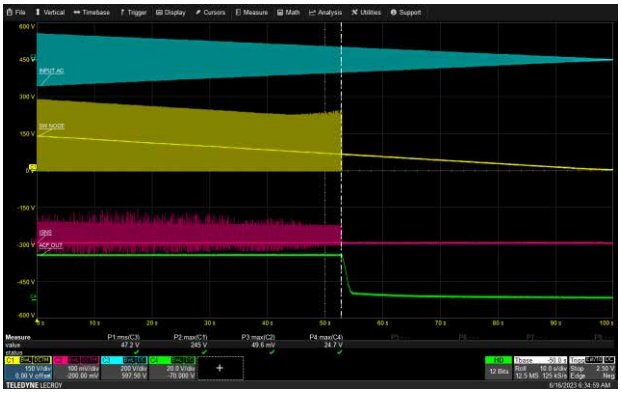
CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output

100 Vac to 0 Vac at 1 Vac/second, 5V/0A (USB-C1)

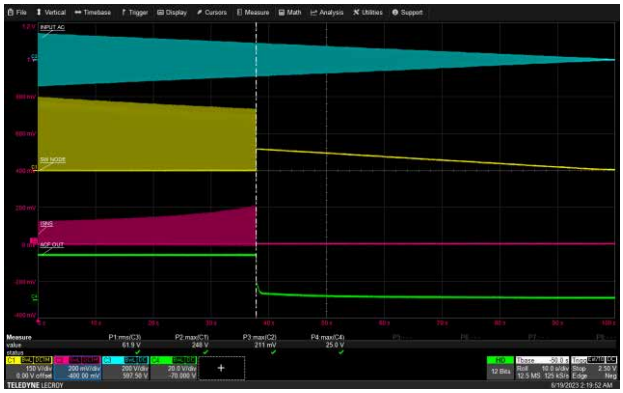
100 Vac to 0 Vac at 1 Vac/second, 5V/3A (USB-C1)

100 Vac to 0 Vac at 1 Vac/second, 9V/0A (USB-C1)

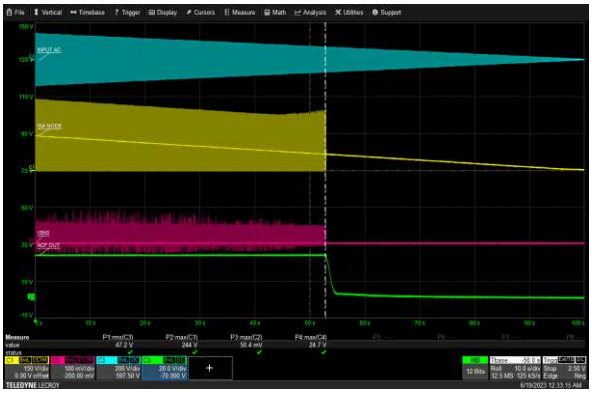
100 Vac to 0 Vac at 1 Vac/second, 9V/3A (USB-C1)



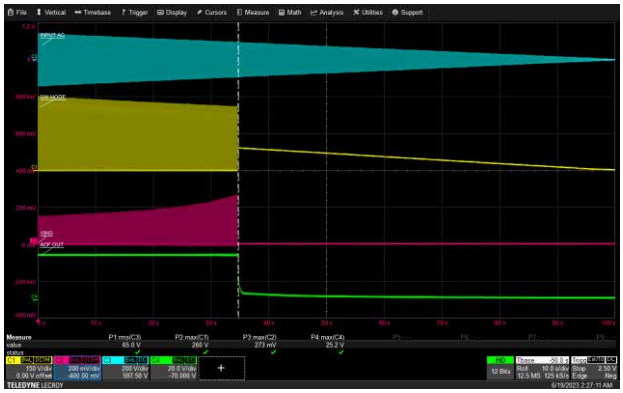
100 Vac to 0 Vac at 1 Vac/second, 12V/0A (USB-C1)



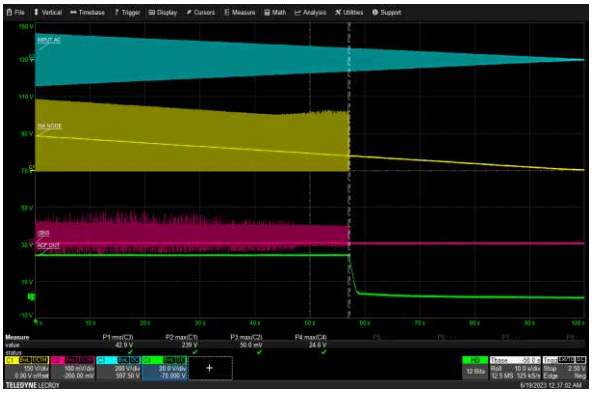
100 Vac to 0 Vac at 1 Vac/second, 12V/3A (USB-C1)



100 Vac to 0 Vac at 1 Vac/second, 15V/0A (USB-C1)



100 Vac to 0 Vac at 1 Vac/second, 15V/3A (USB-C1)



100 Vac to 0 Vac at 1 Vac/second, 20V/0A (USB-C1)

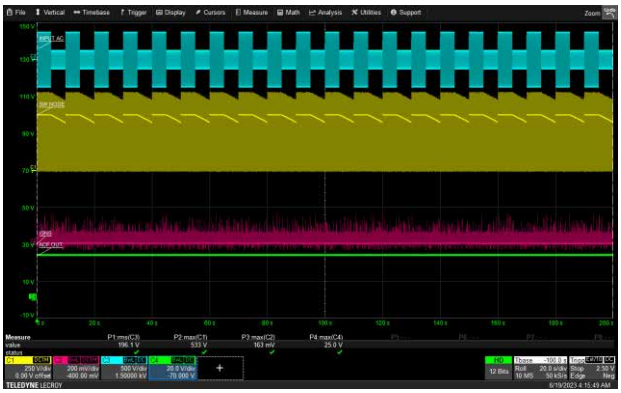
100 Vac to 0 Vac at 1 Vac/second, 20V/3.25A (USB-C1)

Input Line Transient

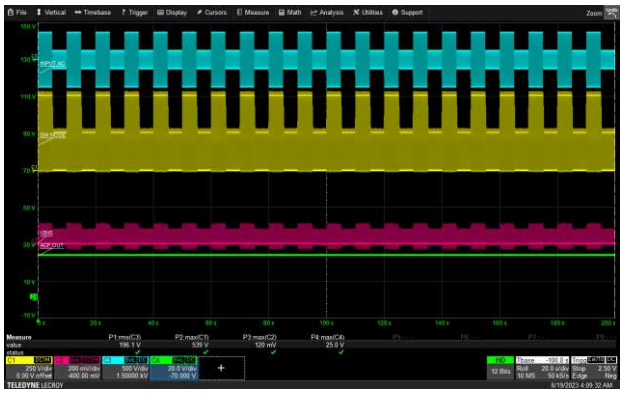
Line disturbances are applied across the input AC terminal. The output of the active clamp flyback supplying the DC-DC block for the USB outputs are monitored during these transient conditions.

- Fast Input Line Transient (20 cycles each of 90 Vac to 265 Vac, 0 Vac to 90 Vac, and 0 Vac to 265 Vac at 5 seconds per AC voltage)

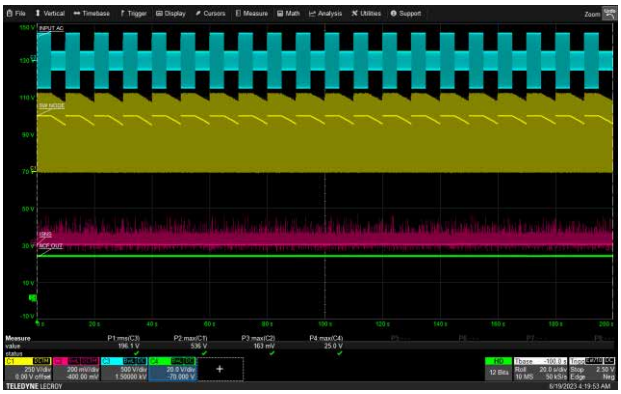
CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output



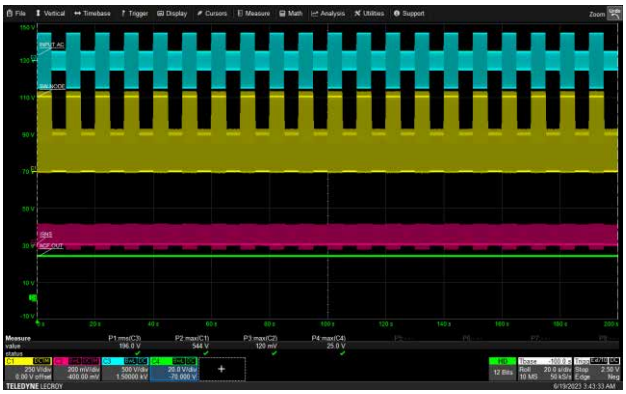
20 cycles of 90 Vac to 265 Vac, 5V/0A (USB-C1)



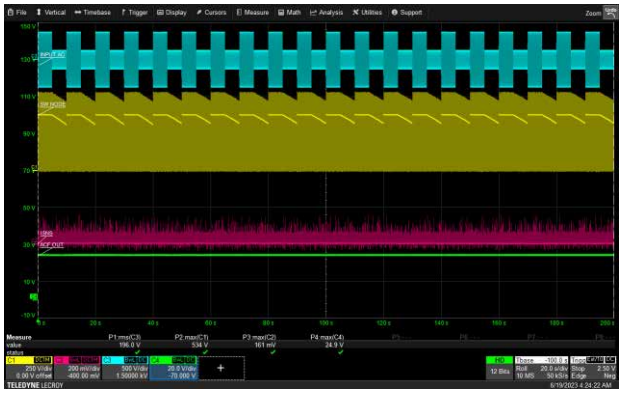
20 cycles of 90 Vac to 265 Vac, 5V/3A (USB-C1)



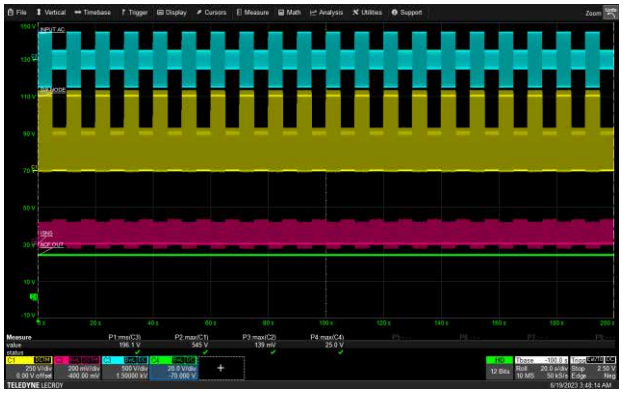
20 cycles of 90 Vac to 265 Vac, 9V/0A (USB-C1)



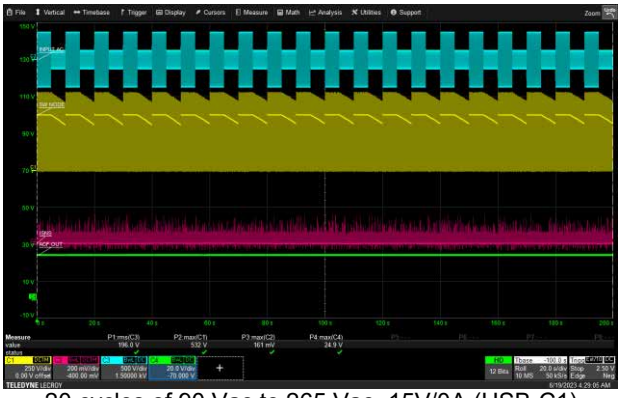
20 cycles of 90 Vac to 265 Vac, 9V/3A (USB-C1)



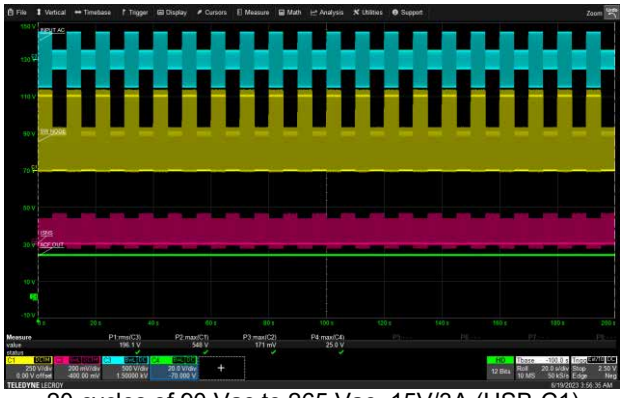
20 cycles of 90 Vac to 265 Vac, 12V/0A (USB-C1)



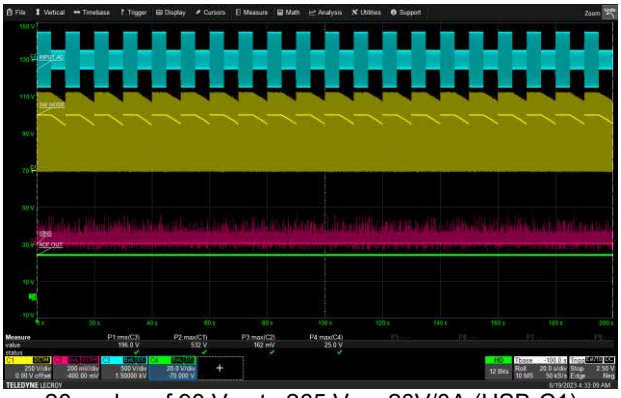
20 cycles of 90 Vac to 265 Vac, 12V/3A (USB-C1)



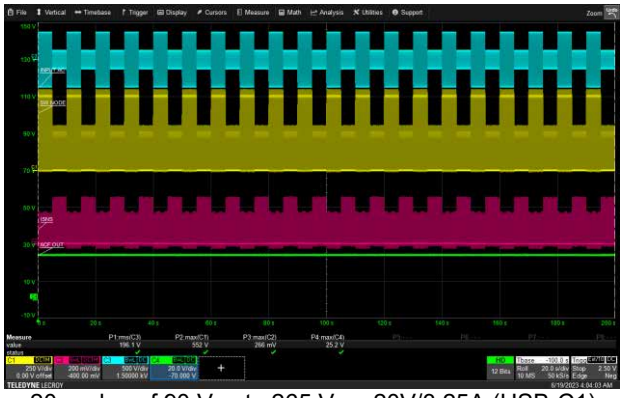
20 cycles of 90 Vac to 265 Vac, 15V/0A (USB-C1)



20 cycles of 90 Vac to 265 Vac, 15V/3A (USB-C1)



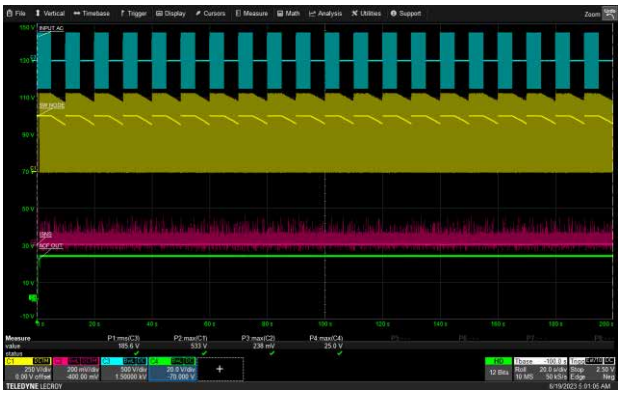
20 cycles of 90 Vac to 265 Vac, 20V/0A (USB-C1)



20 cycles of 90 Vac to 265 Vac, 20V/3.25A (USB-C1)

20 cycles of 0 Vac to 90 Vac, 5V/0A (USB-C1)

20 cycles of 0 Vac to 90 Vac, 5V/3A (USB-C1)

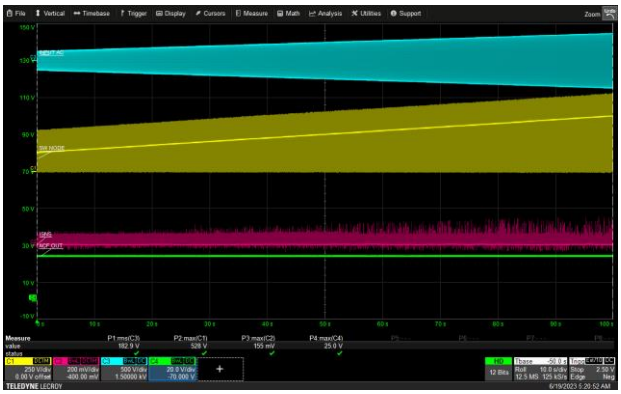


20 cycles of 0 Vac to 265 Vac, 5V/0A (USB-C1)

20 cycles of 0 Vac to 265 Vac, 5V/3A (USB-C1)

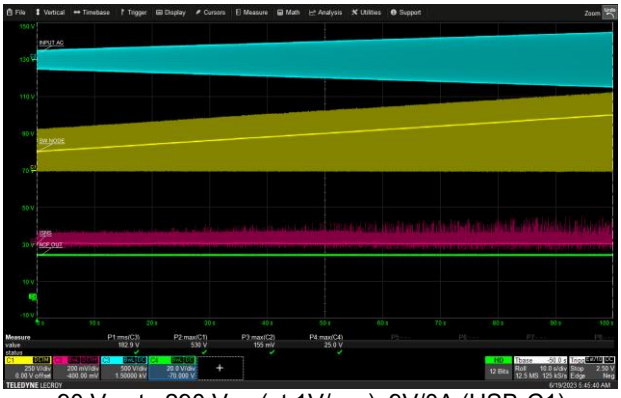
- Slow Input Line Transient (90 Vac to 265 Vac at 1.75 Vac per second)

CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output



90 Vac to 290 Vac (at 1V/sec), 5V/0A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 5V/3A (USB-C1)

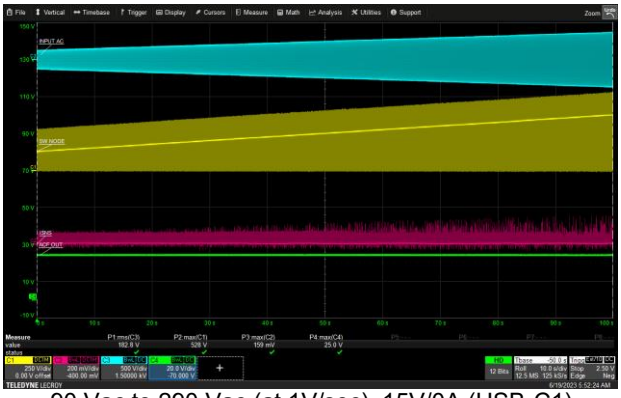


90 Vac to 290 Vac (at 1V/sec), 9V/0A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 9V/3A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 12V/0A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 12V/3A (USB-C1)



90 Vac to 290 Vac (at 1V/sec), 15V/0A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 15V/3A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 20V/0A (USB-C1)

90 Vac to 290 Vac (at 1V/sec), 20V/3.25A (USB-C1)

- Input Line Sag (115 Vac to 75 Vac for 0.5 seconds)

CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output

115 Vac to 75 Vac for 0.5 seconds, 5V/0A (USB-C1)

115 Vac to 75 Vac for 0.5 seconds, 5V/3A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 9V/0A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 9V/3A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 12V/0A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 12V/3A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 15V/0A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 15V/3A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 20V/0A (USB-C1)


115 Vac to 75 Vac for 0.5 seconds, 20V/3.25A (USB-C1)

- Input Line Surge (265 Vac to 290 Vac for 0.5 seconds)

CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: AC Voltage, CH 4: ACF Output

265 Vac to 290 Vac for 0.5 seconds, 5V/0A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 5V/3A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 9V/0A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 9V/3A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 12V/0A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 12V/3A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 15V/0A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 15V/3A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 20V/0A (USB-C1)

265 Vac to 290 Vac for 0.5 seconds, 20V/3.25A (USB-C1)

Timing: Output Voltage Start-up and Turn-on Delay

Measured the total turn-on time from application of input AC voltage to output voltage regulation.

Input AC Voltage	Master USB-C1	Slave USB-C2	Slave USB-A1	Turn-on Time USB-C1	Turn-on Time USB-C2	Turn-on Time USB-A1
90 Vac	5V/0A	5V/0A	5V/0A	1.04 sec	1.19 sec	0.67 sec
	5V/3A	5V/0A	5V/0A	1.03 sec	1.16 sec	0.65 sec
	5V/0A	5V/3A	5V/0A	0.99 sec	1.13 sec	0.62 sec
	5V/0A	5V/0A	5V/3A	1.06 sec	1.19 sec	0.68 sec
265 Vac	5V/0A	5V/0A	5V/0A	1.04 sec	1.17 sec	0.67 sec
	5V/3A	5V/0A	5V/0A	1.02 sec	1.16 sec	0.64 sec
	5V/0A	5V/3A	5V/0A	1.04 sec	1.17 sec	0.65 sec
	5V/0A	5V/0A	5V/3A	1.00 sec	1.18 sec	0.66 sec

CH 1: AC Voltage, CH 2: Master USB-C1 VBUS, CH 3: Slave USB-C2 VBUS, CH 4: Slave USB-A VBUS

Turn-on Time: 90 Vac,5V/3A (USB-C1)

Turn-on Time: 90 Vac,5V/3A (USB-C2)

Turn-on Time: 90 Vac,5V/3A (USB-A1)

Turn-on Time: 265 Vac,5V/3A (USB-C1)

Turn-on Time: 265 Vac,5V/3A (USB-C2)

Turn-on Time: 265 Vac,5V/3A (USB-A1)

Timing: Output Voltage Shutdown and Hold-up Time

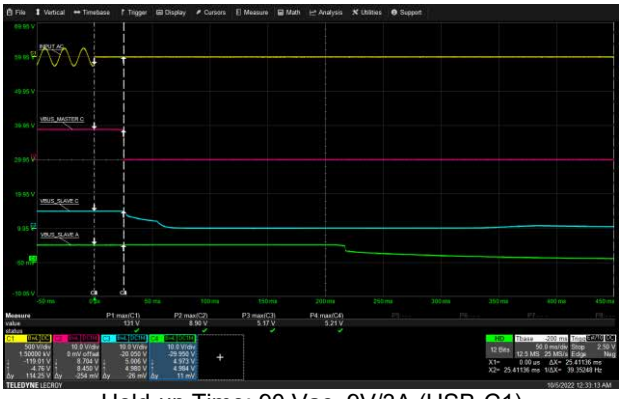
Measured the total hold-up time from loss of input AC voltage to the loss of output voltage regulation.

Input AC Voltage	Output Voltage (100% Load)	Hold-up Time USB-C1	Hold-up Time USB-C2	Hold-up Time USB-A1
90 Vac	5 V	44.16 ms	40.83 ms	39.16 ms
	9 V	25.40 ms	22.91 ms	33.74 ms
	12 V	18.74 ms	19.57 ms	33.26 ms
	15 V	9.58 ms	9.58 ms	
	20 V	7.07 ms	5.41 ms	
265 Vac	5 V	359.58 ms	358.32 ms	360.82 ms
	9 V	212.91 ms	212.49 ms	323.74 ms
	12 V	159.99 ms	163.74 ms	323.74 ms
	15 V	130.82 ms	129.99 ms	
	20 V	87.07 ms	93.32 ms	

CH 1: AC Voltage, CH 2: Master USB-C1 VBUS, CH 3: Slave USB-C2 VBUS, CH 4: Slave USB-A VBUS

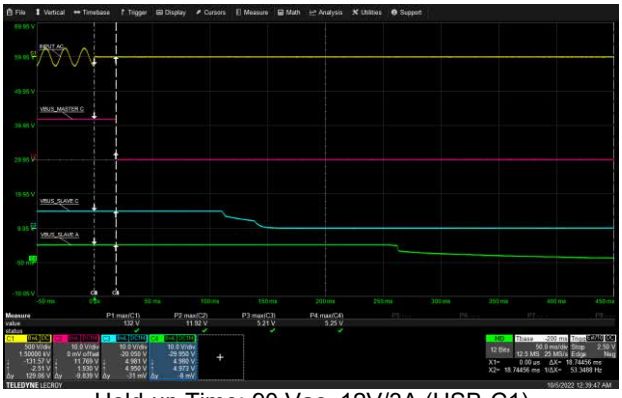
Hold-up Time: 90 Vac, 5V/3A (USB-C1)

Hold-up Time: 265 Vac, 5V/3A (USB-C1)



Hold-up Time: 90 Vac, 9V/3A (USB-C1)

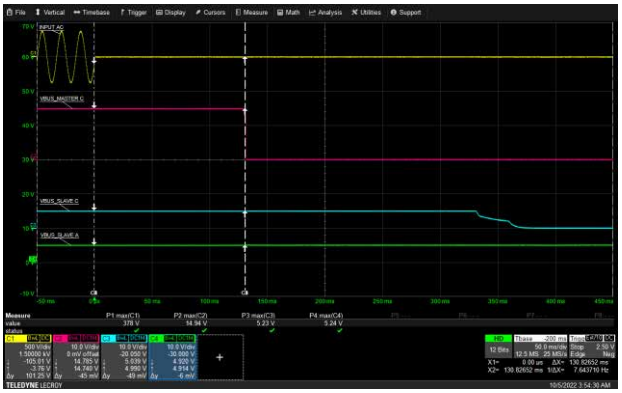
Hold-up Time: 265 Vac, 9V/3A (USB-C1)



Hold-up Time: 90 Vac, 12V/3A (USB-C1)

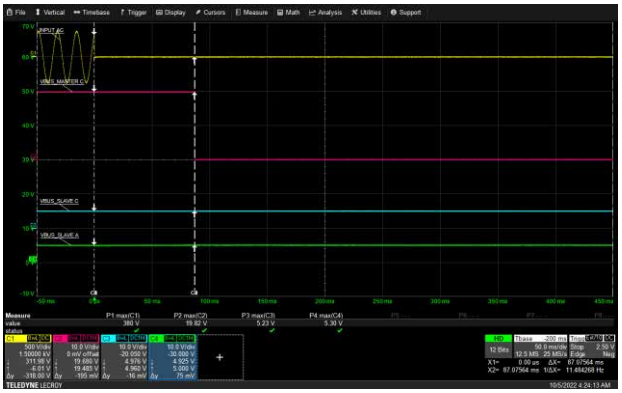
Hold-up Time: 265 Vac, 12V/3A (USB-C1)

Hold-up Time: 90 Vac, 15V/3A (USB-C1)

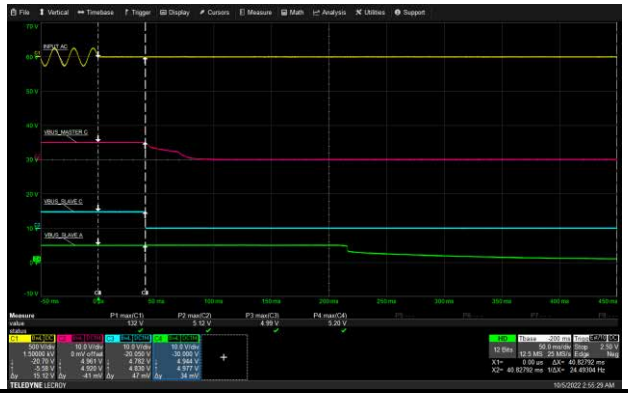


Hold-up Time: 265 Vac, 15V/3A (USB-C1)

Hold-up Time: 90 Vac, 20V/3.25A (USB-C1)

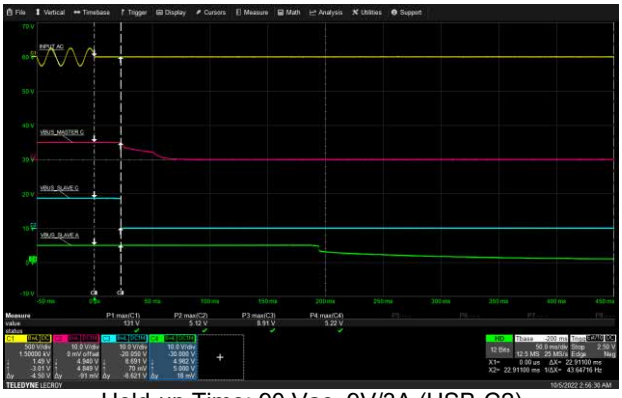


Hold-up Time: 265 Vac, 20V/3.25A (USB-C1)



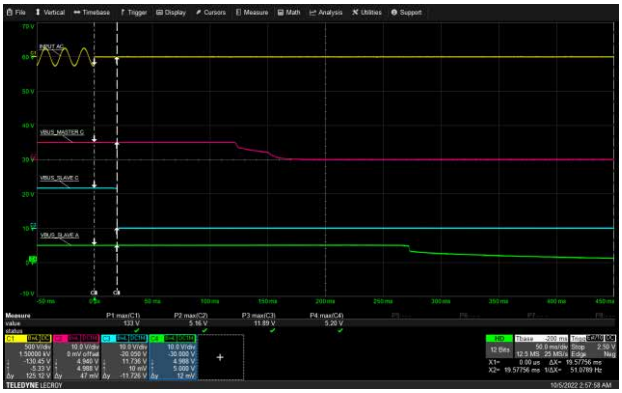
Hold-up Time: 90 Vac, 5V/3A (USB-C2)

Hold-up Time: 265 Vac, 5V/3A (USB-C2)

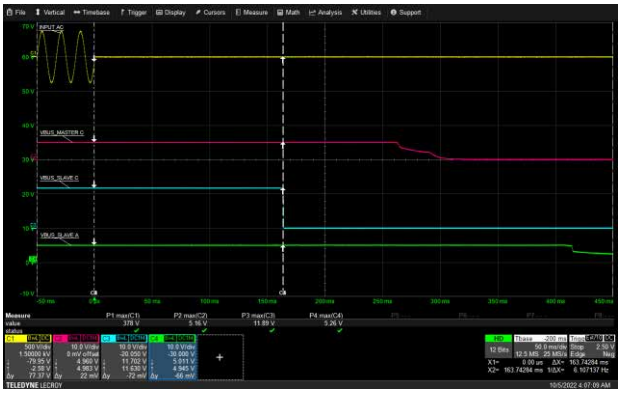


Hold-up Time: 90 Vac, 9V/3A (USB-C2)

Hold-up Time: 265 Vac, 9V/3A (USB-C2)



Hold-up Time: 90 Vac, 12V/3A (USB-C2)

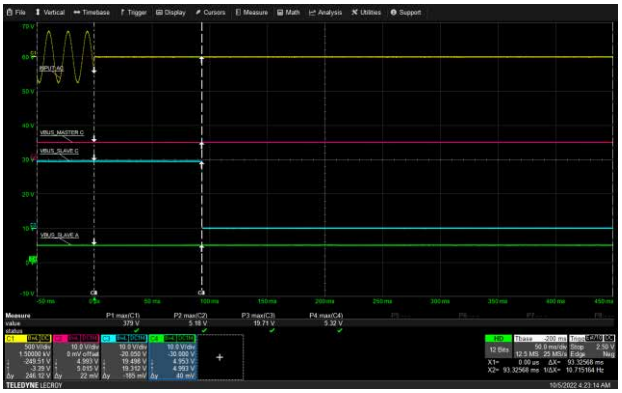


Hold-up Time: 265 Vac, 12V/3A (USB-C2)

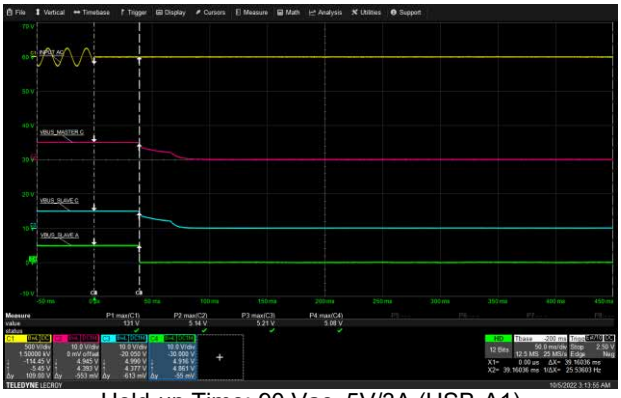
Hold-up Time: 90 Vac, 15V/3A (USB-C2)

Hold-up Time: 265 Vac, 15V/3A (USB-C2)

Hold-up Time: 90 Vac, 20V/3.25A (USB-C2)

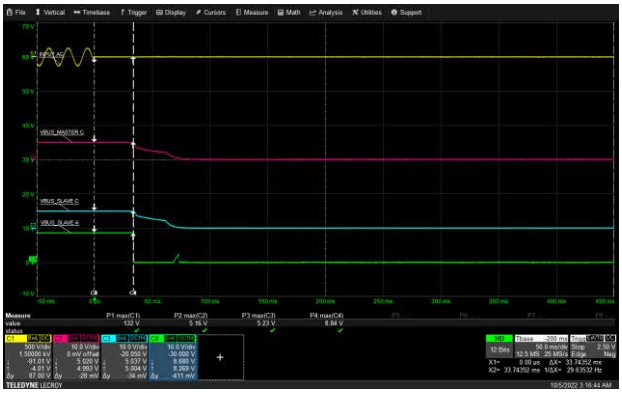


Hold-up Time: 265 Vac, 20V/3.25A (USB-C2)

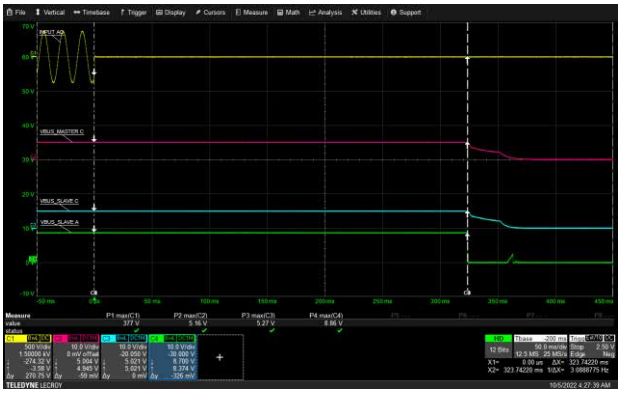


Hold-up Time: 90 Vac, 5V/3A (USB-A1)

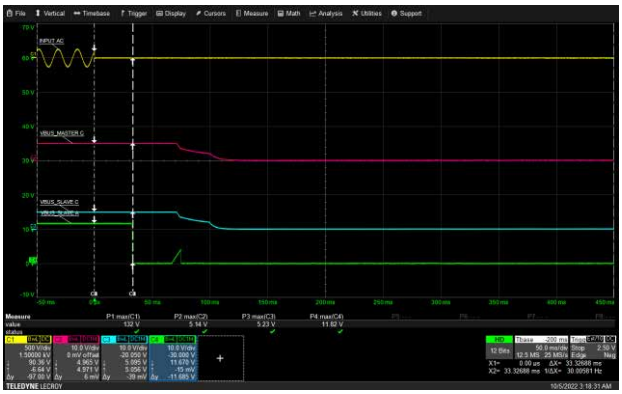
Hold-up Time: 265 Vac, 5V/3A (USB-A1)



Hold-up Time: 90 Vac, 9V/2A (USB-A1)



Hold-up Time: 265 Vac, 9V/2A (USB-A1)



Hold-up Time: 90 Vac, 12V/1.5A (USB-A1)

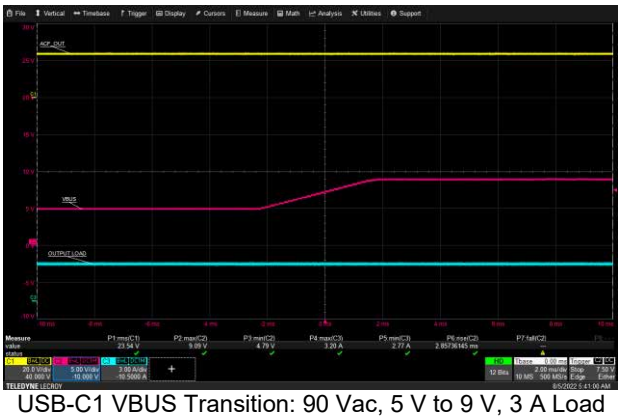
Hold-up Time: 265 Vac, 12V/1.5A (USB-A1)

Timing: USB VBUS Transition, Rise Time, and Fall Time

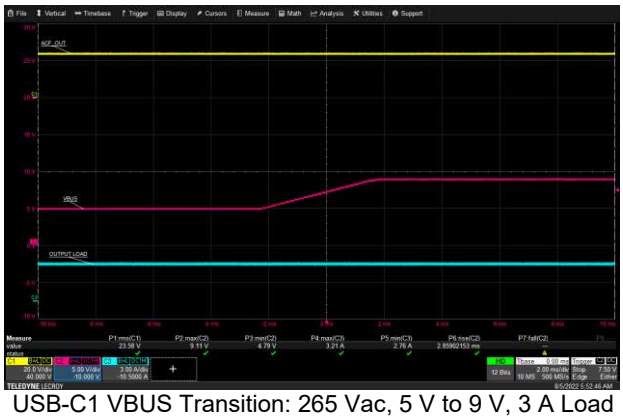
Measured the voltage changes across the VBUS from a corresponding sink request of the upward facing port (UFP) along with the rise and fall time due to the VBUS transition.

USB Port	Input AC Voltage	VBUS Transition	Rise Time Load: 0 A (USB-C1, USB-C2) Load: 0 A (USB-A1)	Rise Time Load: 3 A (USB-C1, USB-C2) Load: 1.5 A (USB-A1)
Master C1	90 Vac	5 V to 9 V	2.94 ms	2.86 ms
		9 V to 12 V	2.16 ms	2.21 ms
		12 V to 15 V	2.10 ms	2.21 ms
		15 V to 20 V	3.73 ms	3.69 ms
	265 Vac	5 V to 9 V	2.97 ms	2.86 ms
		9 V to 12 V	2.16 ms	2.21 ms
		12 V to 15 V	2.09 ms	2.21 ms
		15 V to 20 V	3.66 ms	3.72 ms
Slave C2	90 Vac	5 V to 9 V	3.03 ms	2.91 ms
		9 V to 12 V	2.25 ms	2.25 ms
		12 V to 15 V	2.20 ms	2.25 ms
		15 V to 20 V	3.80 ms	3.71 ms
	265 Vac	5 V to 9 V	3.02 ms	2.91 ms
		9 V to 12 V	2.18 ms	2.25 ms
		12 V to 15 V	2.18 ms	2.24 ms
		15 V to 20 V	3.82 ms	3.75 ms
Slave A1	90 Vac	5 V to 9 V	3.07 ms	3.06 ms
		9 V to 12 V	2.25 ms	2.09 ms
	265 Vac	5 V to 9 V	3.12 ms	3.06 ms
		9 V to 12 V	2.26 ms	2.10 ms

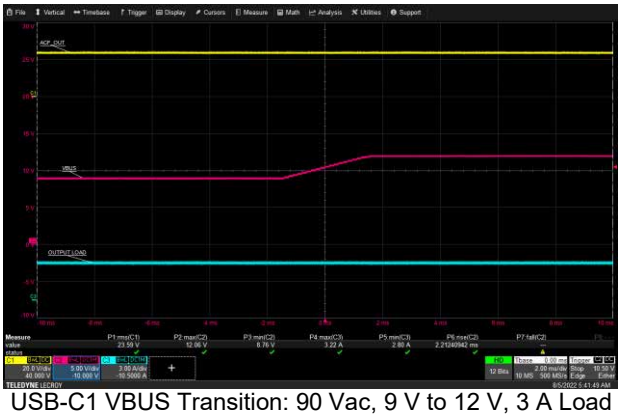
CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load



USB-C1 VBUS Transition: 90 Vac, 5 V to 9 V, 3 A Load



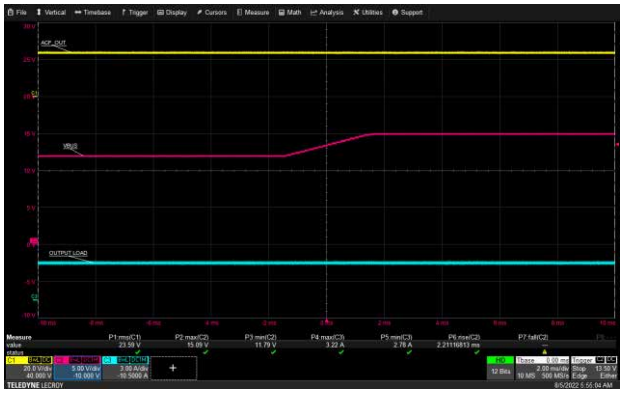
USB-C1 VBUS Transition: 265 Vac, 5 V to 9 V, 3 A Load



USB-C1 VBUS Transition: 90 Vac, 9 V to 12 V, 3 A Load

USB-C1 VBUS Transition: 265 Vac, 9 V to 12 V, 3 A Load

USB-C1 VBUS Transition: 90 Vac, 12 V to 15 V, 3 A Load



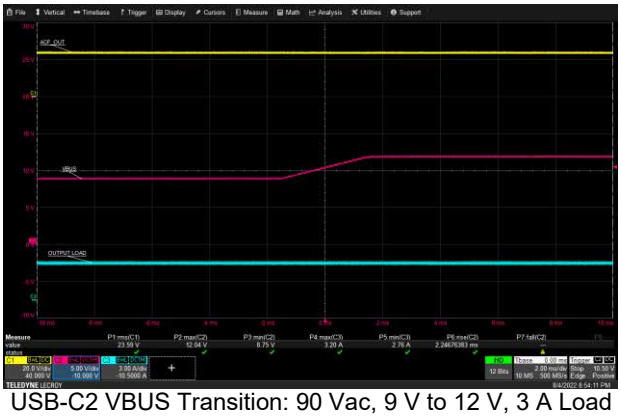
USB-C1 VBUS Transition: 265 Vac, 12 V to 15 V, 3 A Load

USB-C1 VBUS Transition: 90 Vac, 15 V to 20 V, 3 A Load

USB-C1 VBUS Transition: 265 Vac, 15 V to 20 V, 3 A Load

USB-C2 VBUS Transition: 90 Vac, 5 V to 9 V, 3 A Load

USB-C2 VBUS Transition: 265 Vac, 5 V to 9 V, 3 A Load



USB-C2 VBUS Transition: 90 Vac, 9 V to 12 V, 3 A Load

USB-C2 VBUS Transition: 265 Vac, 9 V to 12 V, 3 A Load

USB-C2 VBUS Transition: 90 Vac, 12 V to 15 V, 3 A Load

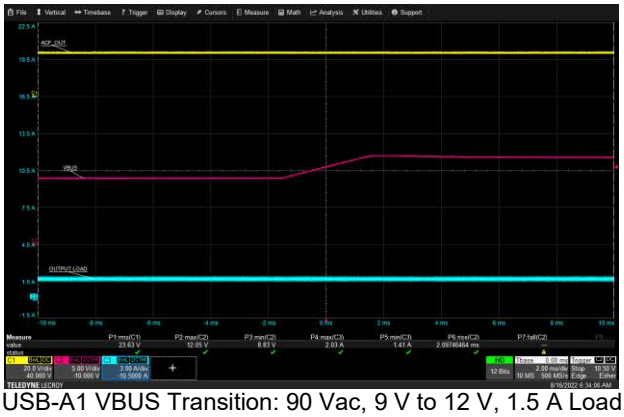
USB-C2 VBUS Transition: 265 Vac, 12 V to 15 V, 3 A Load

USB-C2 VBUS Transition: 90 Vac, 15 V to 20 V, 3 A Load

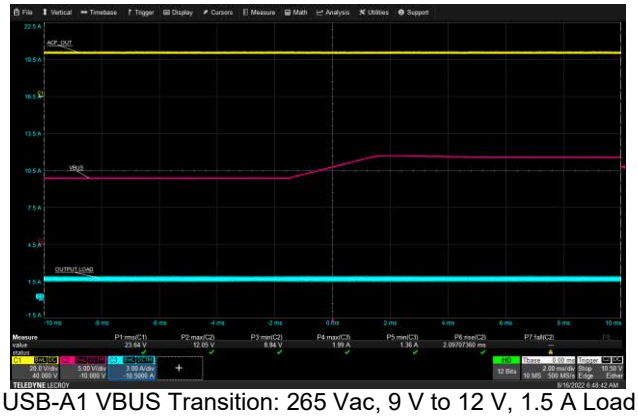
USB-C2 VBUS Transition: 265 Vac, 15 V to 20 V, 3 A Load

USB-A1 VBUS Transition: 90 Vac, 5 V to 9 V, 1.5 A Load

USB-A1 VBUS Transition: 265 Vac, 5 V to 9 V, 1.5 A Load



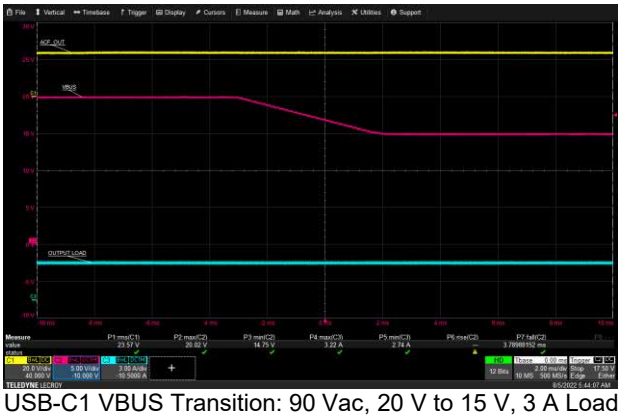
USB-A1 VBUS Transition: 90 Vac, 9 V to 12 V, 1.5 A Load



USB-A1 VBUS Transition: 265 Vac, 9 V to 12 V, 1.5 A Load

USB Port	Input AC Voltage	VBUS Transition	Fall Time Load: 0 A (USB-C1, USB-C2) Load: 0 A (USB-A1)	Fall Time Load: 3 A (USB-C1, USB-C2) Load: 1.5 A (USB-A1)
Master C1	90 Vac	20 V to 15 V	3.79 ms	3.79 ms
		15 V to 12 V	2.21 ms	2.21 ms
		12 V to 9 V	2.21 ms	2.21 ms
		9 V to 5 V	2.86 ms	3.00 ms
	265 Vac	20 V to 15 V	3.79 ms	3.79 ms
		15 V to 12 V	2.21 ms	2.21 ms
		12 V to 9 V	2.21 ms	2.21 ms
		9 V to 5 V	3.00 ms	3.00 ms
Slave C2	90 Vac	20 V to 15 V	3.79 ms	3.77 ms
		15 V to 12 V	2.30 ms	2.25 ms
		12 V to 9 V	2.23 ms	2.25 ms
		9 V to 5 V	2.29 ms	2.90 ms
	265 Vac	20 V to 15 V	3.82 ms	3.84 ms
		15 V to 12 V	2.23 ms	2.25 ms
		12 V to 9 V	2.23 ms	2.25 ms
		9 V to 5 V	2.91 ms	3.01 ms
Slave A1	90 Vac	12 V to 9 V	2.26 ms	2.24 ms
		9 V to 5 V	3.09 ms	3.07 ms
	265 Vac	12 V to 9 V	2.25 ms	2.23 ms
		9 V to 5 V	2.91 ms	3.06 ms

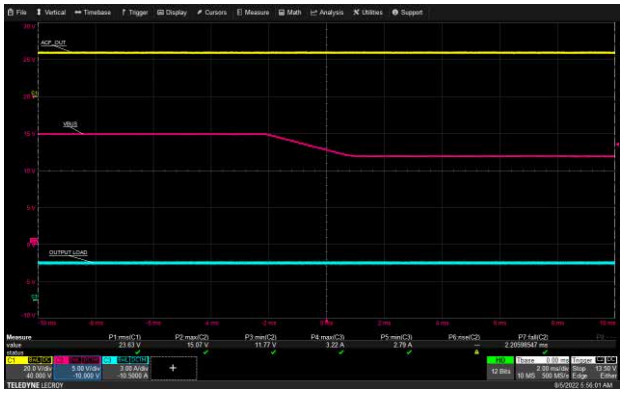
CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load



USB-C1 VBUS Transition: 90 Vac, 20 V to 15 V, 3 A Load

USB-C1 VBUS Transition: 265 Vac, 20 V to 15 V, 3 A Load


USB-C1 VBUS Transition: 90 Vac, 15 V to 12 V, 3 A Load


USB-C1 VBUS Transition: 265 Vac, 15 V to 12 V, 3 A Load


USB-C1 VBUS Transition: 90 Vac, 12 V to 9 V, 3 A Load


USB-C1 VBUS Transition: 265 Vac, 12 V to 9 V, 3 A Load

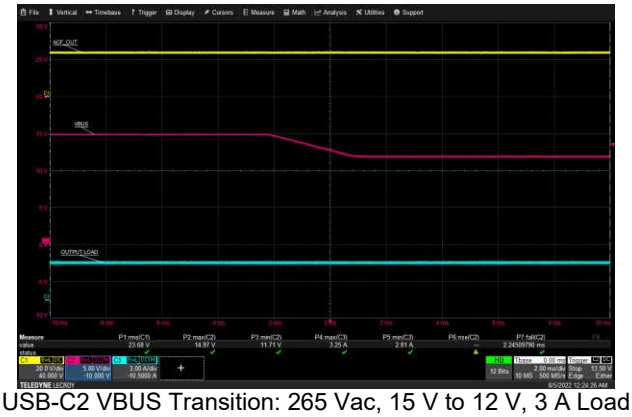

USB-C1 VBUS Transition: 90 Vac, 9 V to 5 V, 3 A Load


USB-C1 VBUS Transition: 265 Vac, 9 V to 5 V, 3 A Load


USB-C2 VBUS Transition: 90 Vac, 20 V to 15 V, 3 A Load


USB-C2 VBUS Transition: 265 Vac, 20 V to 15 V, 3 A Load


USB-C2 VBUS Transition: 90 Vac, 15 V to 12 V, 3 A Load

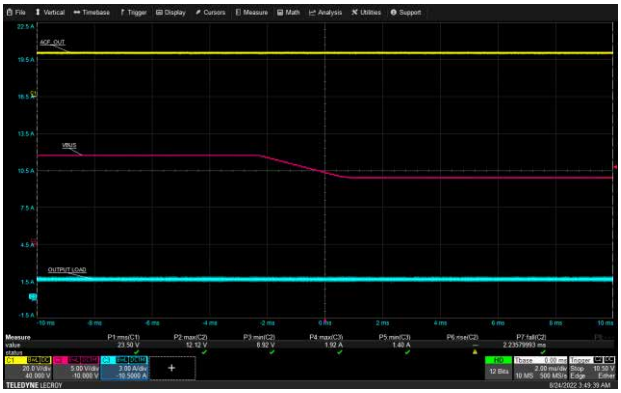

USB-C2 VBUS Transition: 265 Vac, 15 V to 12 V, 3 A Load

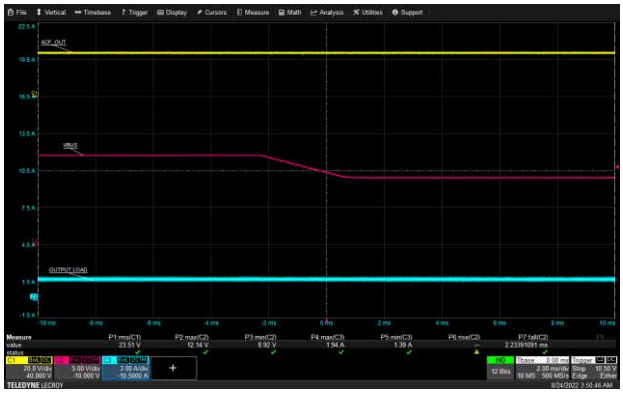

USB-C2 VBUS Transition: 90 Vac, 12 V to 9 V, 3 A Load

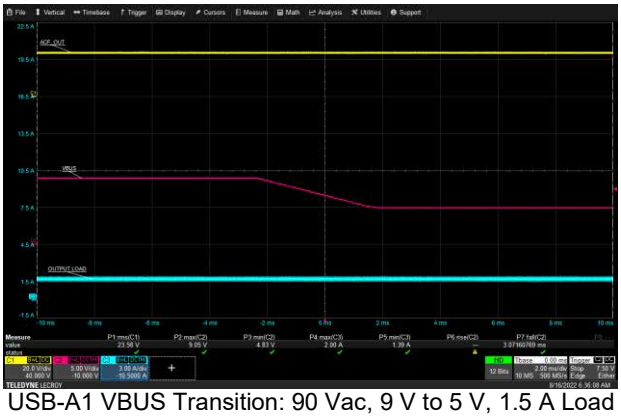

USB-C2 VBUS Transition: 265 Vac, 12 V to 9 V, 3 A Load


USB-C2 VBUS Transition: 90 Vac, 9 V to 5 V, 3 A Load

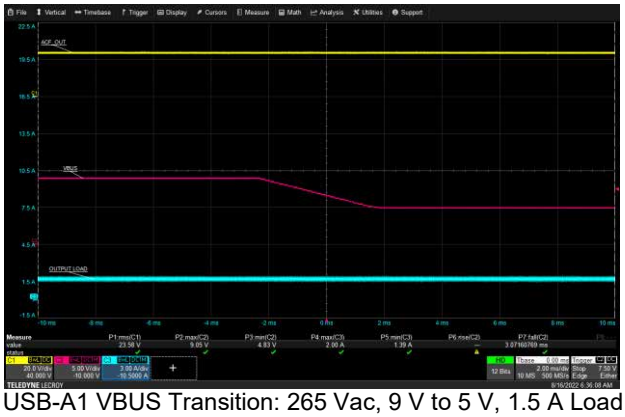

USB-C2 VBUS Transition: 265 Vac, 9 V to 5 V, 3 A Load


USB-A1 VBUS Transition: 90 Vac, 12 V to 9 V, 1.5 A Load


USB-A1 VBUS Transition: 265 Vac, 12 V to 9 V, 1.5 A Load



USB-A1 VBUS Transition: 90 Vac, 9 V to 5 V, 1.5 A Load



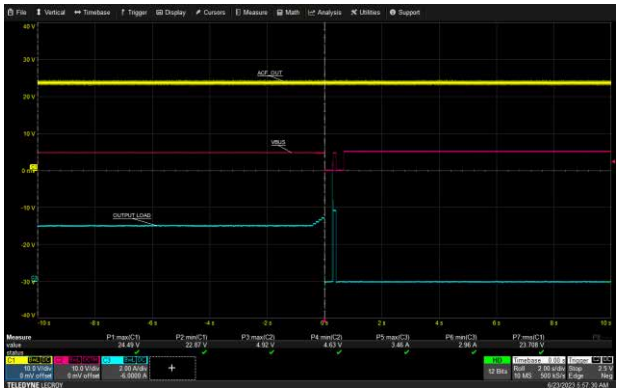
USB-A1 VBUS Transition: 265 Vac, 9 V to 5 V, 1.5 A Load

Fault Response: VBUS Over-Current Protection

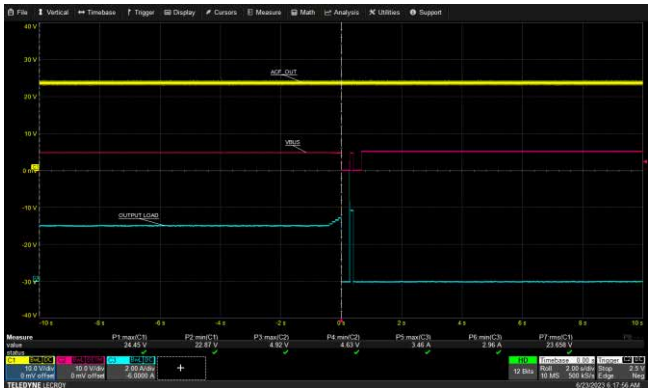
Measured the maximum current limit for each USB port upon application of increasing load current across the port until VBUS shutdown (for USB-PD) or maximum power is reached (for USB-A QC2.0/3.0). When overcurrent was removed, the VBUS should be able to recover to the default VBUS level.

USB Port	Input AC Voltage	PDO Setting	Over Current Limit
Master C1	90 Vac	5 V	3.46 A
		9 V	3.64 A
		12 V	3.64 A
		15 V	3.66 A
		20 V	3.75 A
	265 Vac	5 V	3.46 A
		9 V	3.66 A
		12 V	3.66 A
		15 V	3.65 A
		20 V	3.66 A
Slave C2	90 Vac	5 V	3.57 A
		9 V	3.64 A
		12 V	3.64 A
		15 V	3.64 A
		20 V	3.76 A
	265 Vac	5 V	3.46 A
		9 V	3.66 A
		12 V	3.61 A
		15 V	3.66 A
		20 V	3.66 A

CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load



USB-C1 Over Current Protection: 90 Vac, 5 V



USB-C1 Over Current Protection: 265 Vac, 5 V

USB-C1 Over Current Protection: 90 Vac, 9 V

USB-C1 Over Current Protection: 265 Vac, 9 V

USB-C1 Over Current Protection: 90 Vac, 12 V

USB-C1 Over Current Protection: 265 Vac, 12 V

USB-C1 Over Current Protection: 90 Vac, 15 V

USB-C1 Over Current Protection: 265 Vac, 15 V

USB-C1 Over Current Protection: 90 Vac, 20 V

USB-C1 Over Current Protection: 265 Vac, 20 V

USB-C2 Over Current Protection: 90 Vac, 5 V

USB-C2 Over Current Protection: 265 Vac, 5 V

USB-C2 Over Current Protection: 90 Vac, 9 V

USB-C2 Over Current Protection: 265 Vac, 9 V

USB-C2 Over Current Protection: 90 Vac, 12 V

USB-C2 Over Current Protection: 265 Vac, 12 V

USB-C2 Over Current Protection: 90 Vac, 15 V

USB-C2 Over Current Protection: 265 Vac, 15 V

USB-C2 Over Current Protection: 90 Vac, 20 V

USB-C2 Over Current Protection: 265 Vac, 20 V

USB Port	Input AC Voltage	QC2.0 Setting	Max Power Limit	Max Current Before Retry
Slave A1	90 Vac	5 V	16.0 W	3.26 A
		9 V	19.0 W	3.26 A
		12 V	19.5 W	3.25 A
	265 Vac	5 V	15.9 W	3.25 A
		9 V	18.9 W	3.25 A
		12 V	19.3 W	3.24 A

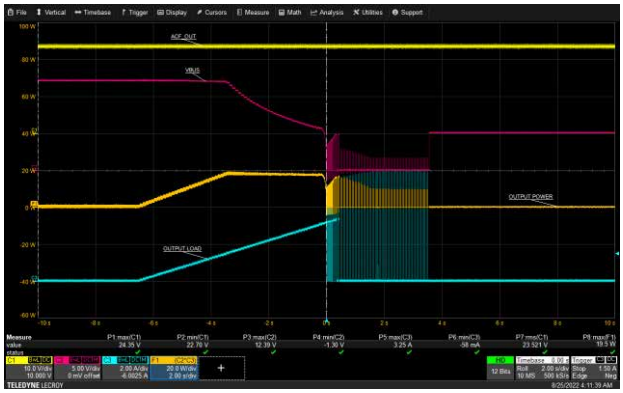
CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load

USB-A1 Over Current Protection: 90 Vac, 5 V

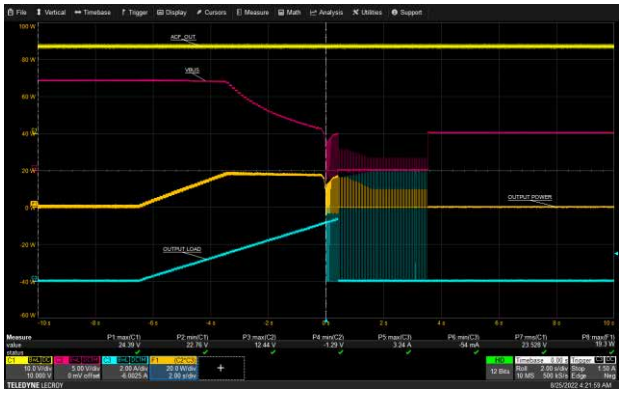
USB-A1 Over Current Protection: 265 Vac, 5 V

USB-A1 Over Current Protection: 90 Vac, 9 V

USB-A1 Over Current Protection: 265 Vac, 9 V



USB-A1 Over Current Protection: 90 Vac, 12 V



USB-A1 Over Current Protection: 265 Vac, 12 V

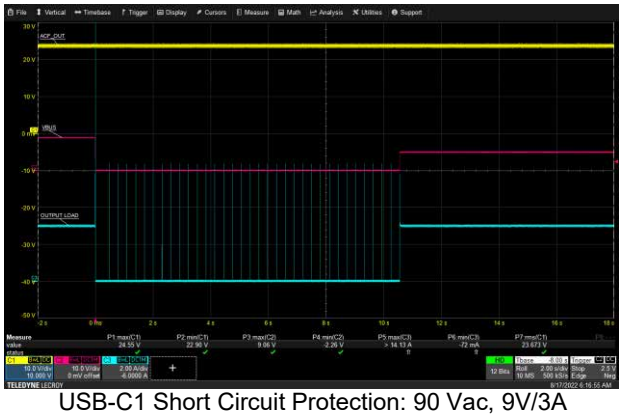
Fault Response: VBUS Short Circuit Protection

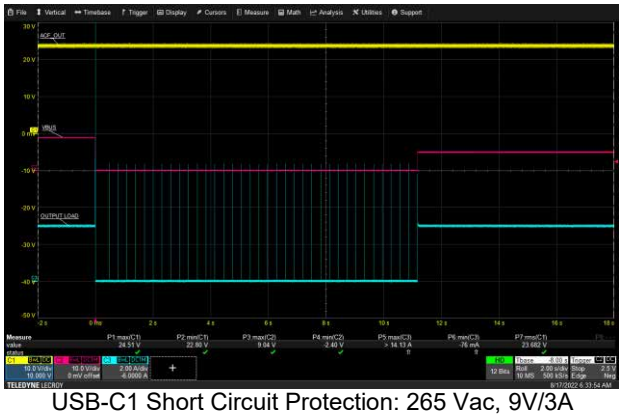
Monitored the behaviour of the VBUS at the instance of a short circuit fault across the corresponding USB port. When the short circuit fault was removed, the VBUS should be able to recover to the default VBUS level.

CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load

USB-C1 Short Circuit Protection: 90 Vac, 5V/3A

USB-C1 Short Circuit Protection: 265 Vac, 5V/3A


USB-C1 Short Circuit Protection: 90 Vac, 9V/3A


USB-C1 Short Circuit Protection: 265 Vac, 9V/3A


USB-C1 Short Circuit Protection: 90 Vac, 12V/3A

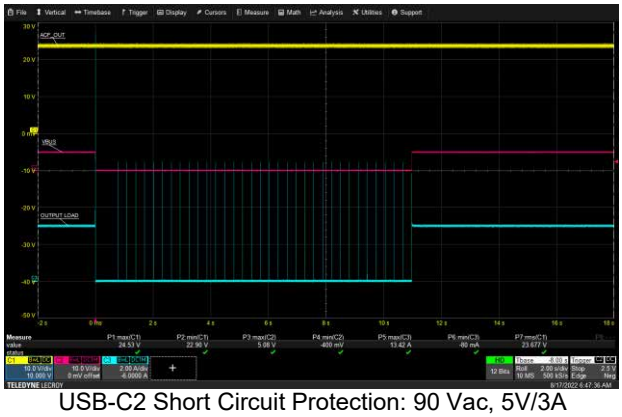

USB-C1 Short Circuit Protection: 265 Vac, 12V/3A


USB-C1 Short Circuit Protection: 90 Vac, 15V/3A

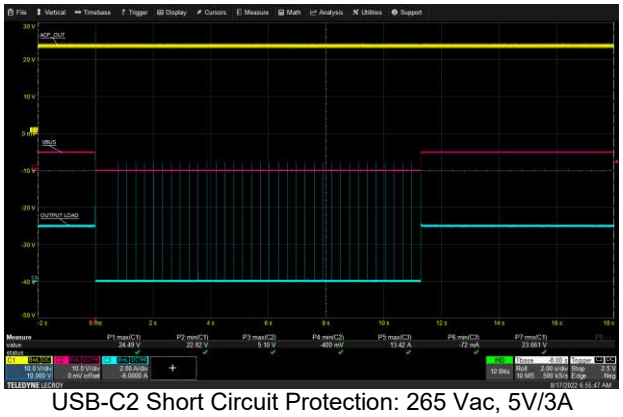

USB-C1 Short Circuit Protection: 265 Vac, 15V/3A


USB-C1 Short Circuit Protection: 90 Vac, 20V/3.25A


USB-C1 Short Circuit Protection: 265 Vac, 20V/3.25A



USB-C2 Short Circuit Protection: 90 Vac, 5V/3A



USB-C2 Short Circuit Protection: 265 Vac, 5V/3A

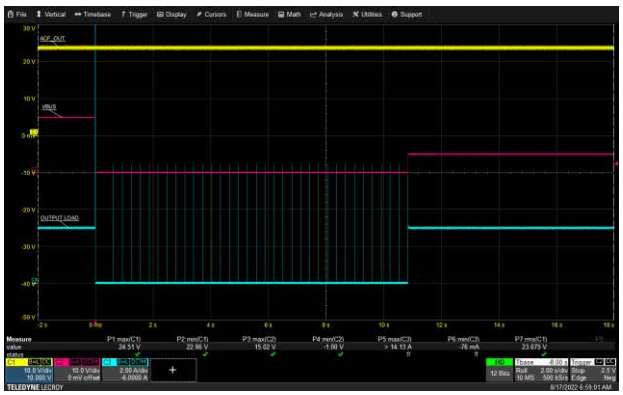
USB-C2 Short Circuit Protection: 90 Vac, 9V/3A

USB-C2 Short Circuit Protection: 265 Vac, 9V/3A

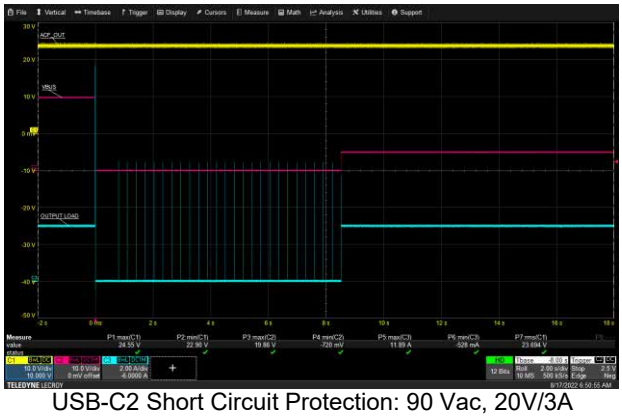
USB-C2 Short Circuit Protection: 90 Vac, 12V/3A

USB-C2 Short Circuit Protection: 265 Vac, 12V/3A

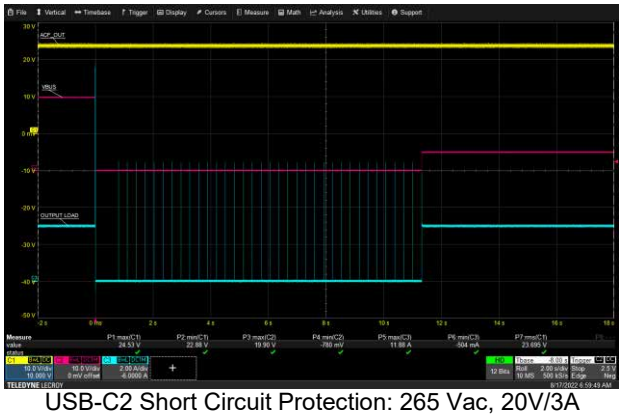
USB-C2 Short Circuit Protection: 90 Vac, 15V/3A



USB-C2 Short Circuit Protection: 265 Vac, 15V/3A



USB-C2 Short Circuit Protection: 90 Vac, 20V/3A



USB-C2 Short Circuit Protection: 265 Vac, 20V/3A

USB-A1 Short Circuit Protection: 90 Vac, 5V/3A

USB-A1 Short Circuit Protection: 265 Vac, 5V/3A

USB-A1 Short Circuit Protection: 90 Vac, 9V/2A

USB-A1 Short Circuit Protection: 265 Vac, 9V/2A

USB-A1 Short Circuit Protection: 90 Vac, 12V/1.5A

USB-A1 Short Circuit Protection: 265 Vac, 12V/1.5A

Fault Response: VBUS Over-Voltage Protection

Monitored the behaviour of VBUS at the instance of an over-voltage fault. This condition was triggered by shorting the SZPL3002A Feedback pin to ground and checking the maximum voltage that the VBUS will increase before shutdown. When the over-voltage fault was removed, the VBUS should be able to recover to the default VBUS level.

USB Port	Input AC Voltage	PDO Setting	Maximum VBUS before Shutdown (Load: 0 A)	Maximum VBUS before Shutdown (Load: 3 A)
Master C1	90 Vac	5 V	5.39	5.29
		9 V	9.21	9.20
		12 V	12.29	12.22
		15 V	15.28	15.26
		20 V	20.51	20.19
	265 Vac	5 V	5.57	5.30
		9 V	9.23	9.24
		12 V	12.32	12.21
		15 V	15.33	15.27
		20 V	20.55	20.18
Slave C2	90 Vac	5 V	5.41	5.26
		9 V	9.21	9.12
		12 V	12.27	12.13
		15 V	15.29	15.25
		20 V	20.53	19.98
	265 Vac	5 V	5.26	5.24
		9 V	9.21	9.12
		12 V	12.25	12.19
		15 V	15.28	15.14
		20 V	20.53	20.06

CH 1: ACF_OUT (DCDC Input), CH 2: USB VBUS, CH 3: USB VBUS Load

USB-C1 Over Voltage Protection: 90 Vac, 5V/3A

USB-C1 Over Voltage Protection: 265 Vac, 5V/3A

USB-C1 Over Voltage Protection: 90 Vac, 9V/3A

USB-C1 Over Voltage Protection: 265 Vac, 9V/3A

USB-C1 Over Voltage Protection: 90 Vac, 12V/3A

USB-C1 Over Voltage Protection: 265 Vac, 12V/3A

USB-C1 Over Voltage Protection: 90 Vac, 15V/3A

USB-C1 Over Voltage Protection: 265 Vac, 15V/3A

USB-C1 Over Voltage Protection: 90 Vac, 20V/3.25A

USB-C1 Over Voltage Protection: 265 Vac, 20V/3.25A

USB-C2 Over Voltage Protection: 90 Vac, 5V/3A

USB-C2 Over Voltage Protection: 265 Vac, 5V/3A

USB-C2 Over Voltage Protection: 90 Vac, 9V/3A

USB-C2 Over Voltage Protection: 265 Vac, 9V/3A

USB-C2 Over Voltage Protection: 90 Vac, 12V/3A

USB-C2 Over Voltage Protection: 265 Vac, 12V/3A

USB-C2 Over Voltage Protection: 90 Vac, 15V/3A

USB-C2 Over Voltage Protection: 265 Vac, 15V/3A

USB-C2 Over Voltage Protection: 90 Vac, 20V/3.25A

USB-C2 Over Voltage Protection: 265 Vac, 20V/3.25A

Fault Response: ACF_OUT Short Circuit Protection

Monitored the behaviour of the output of the Active Clamp Flyback (ACF) to the input of the DCDC stage during an instance of short circuit across its output. SZ1131 auto-retries during ACF output short circuit and recovers upon removal of fault.

Input AC Voltage	Maximum SW Node Voltage During SCKT	Average Input Power during Continuous Short Circuit (10 minutes)
90 Vac	282 V	58.84 mW
265 Vac	548 V	187.79 mW

CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: SZ1131 VCC, CH 4: ACF_OUT

ACF_OUT Startup Short Circuit: 90 Vac

ACF_OUT Startup Short Circuit: 265 Vac

ACF_OUT Running Short Circuit: 90 Vac, 5V/3A USB-C1

ACF_OUT Running Short Circuit: 265 Vac, 5V/3A USB-C1

ACF_OUT Running Short Circuit: 90 Vac, 9V/3A USB-C1

ACF_OUT Running Short Circuit: 265 Vac, 9V/3A USB-C1

ACF_OUT Running Short Circuit: 90 Vac, 12V/3A USB-C1

ACF_OUT Running Short Circuit: 265 Vac, 12V/3A USB-C1

ACF_OUT Running Short Circuit: 90 Vac, 15V/3A USB-C1

ACF_OUT Running Short Circuit: 265 Vac, 15V/3A USB-C1

ACF_OUT Running Short Circuit: 90 Vac, 20V/3.25A USB-C1

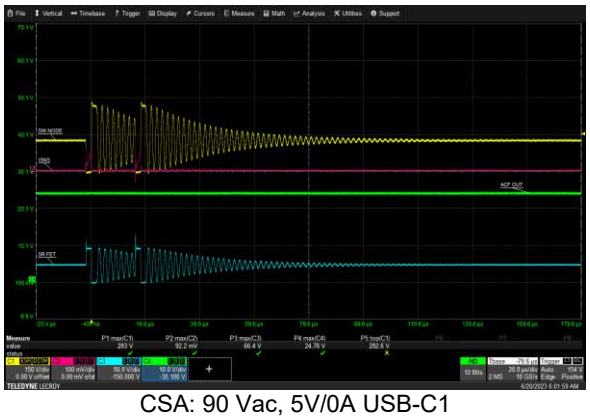
ACF_OUT Running Short Circuit: 265 Vac, 20V/3.25A USB-C1

Component Stress Analysis: Primary FET Switch and Secondary SR FET

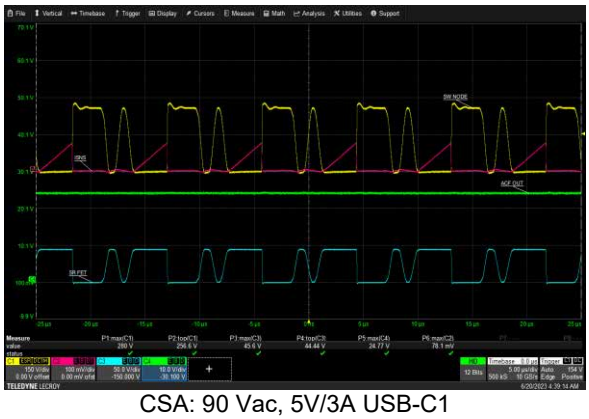
Measured the voltage stress on the Primary FET Switch and Secondary SR FET of the Active Clamp Flyback (ACF) section of the reference design.

Input AC Voltage	USB-C1 PDO Setting	Maximum Primary SW Node Voltage (0% Load)	Maximum Primary SW Node Voltage (100% Load)	Maximum Secondary SR FET Voltage (0% Load)	Maximum Secondary SR FET Voltage (100% Load)
90 Vac	5 V	283 V	280 V	45.6 V	66.4 V
	9 V	283 V	282 V	45.5 V	66.4 V
	12 V	282 V	285 V	45.5 V	66.7 V
	15 V	283 V	288 V	45.1 V	65.5 V
	20 V	282 V	297 V	43.6 V	58.4 V
265 Vac	5 V	534 V	536 V	121.8 V	111.0 V
	9 V	535 V	541 V	121.7 V	109.4 V
	12 V	533 V	546 V	121.5 V	110.0 V
	15 V	535 V	546 V	121.3 V	109.4 V
	20 V	532 V	549 V	121.0 V	108.2 V

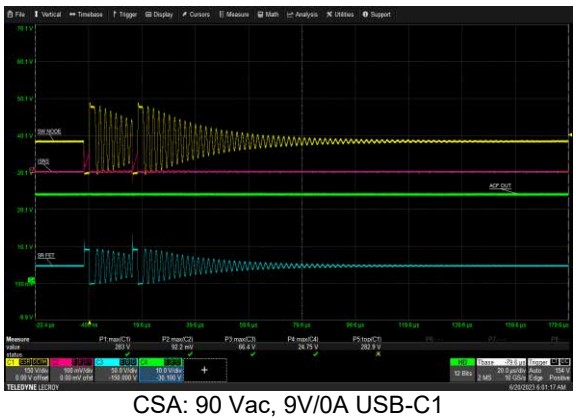
CH 1: ACF SW Node, CH 2: ACF ISNS Voltage, CH 3: ACF Secondary SR FET, CH 4: ACF_OUT



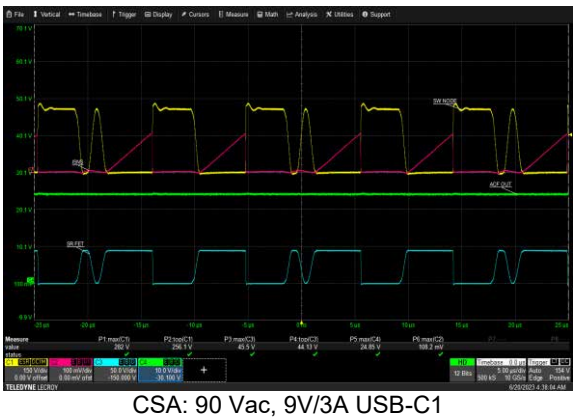
CSA: 90 Vac, 5V/0A USB-C1



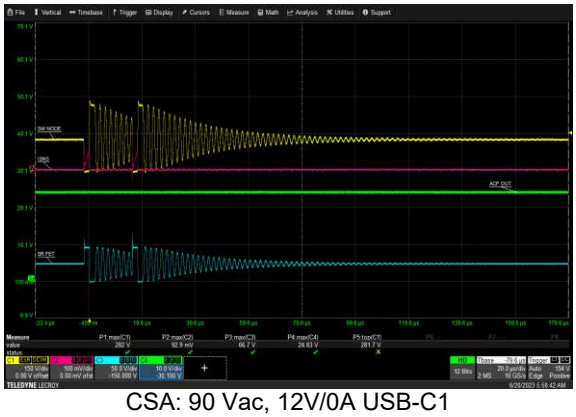
CSA: 90 Vac, 5V/3A USB-C1



CSA: 90 Vac, 9V/0A USB-C1



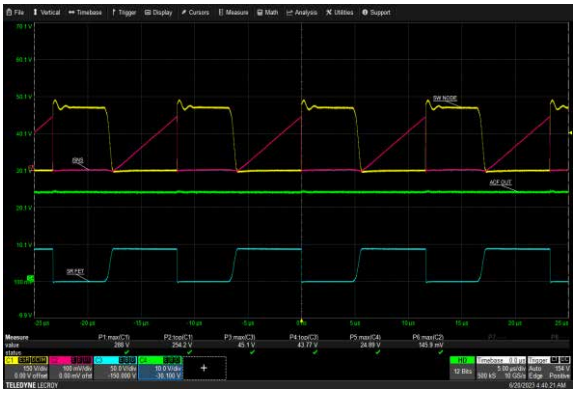
CSA: 90 Vac, 9V/3A USB-C1



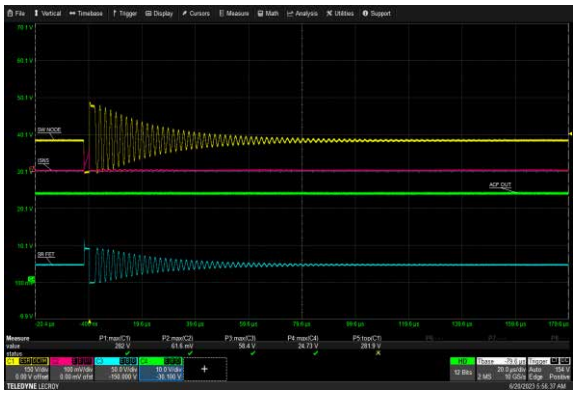
CSA: 90 Vac, 12V/0A USB-C1

CSA: 90 Vac, 12V/3A USB-C1

CSA: 90 Vac, 15V/0A USB-C1

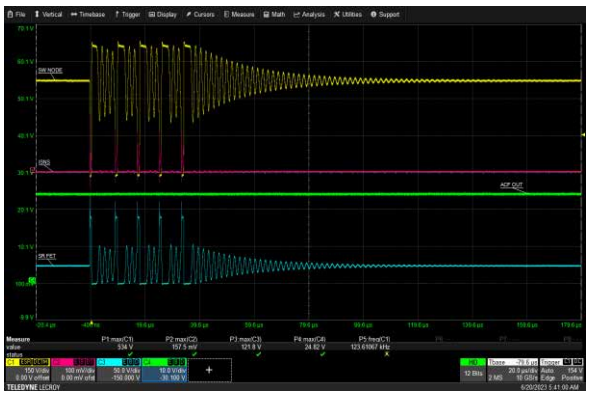


CSA: 90 Vac, 15V/3A USB-C1



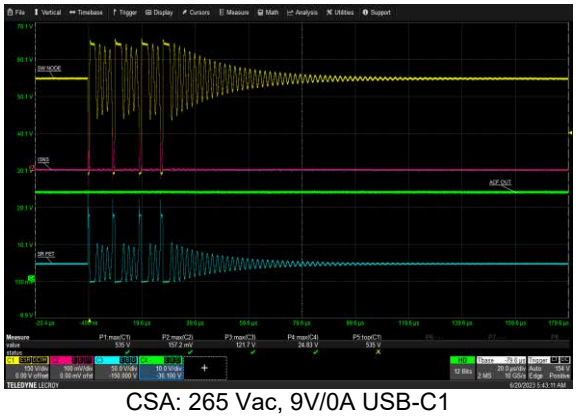
CSA: 90 Vac, 20V/0A USB-C1

CSA: 90 Vac, 20V/3.25A USB-C1

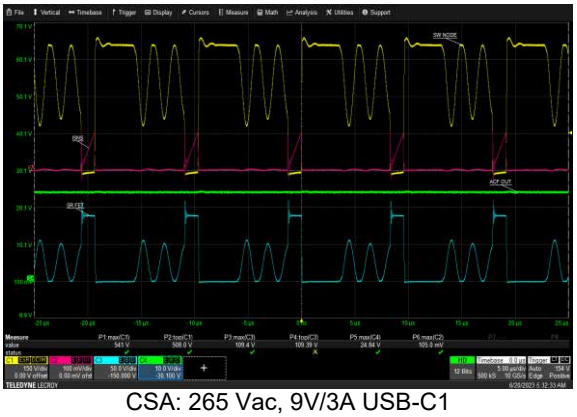


CSA: 265 Vac, 5V/0A USB-C1

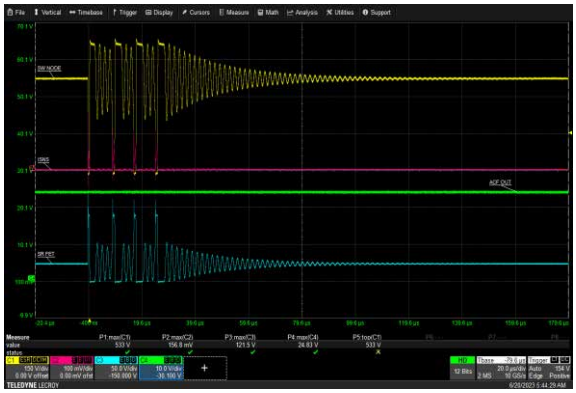
CSA: 265 Vac, 5V/3A USB-C1



CSA: 265 Vac, 9V/0A USB-C1

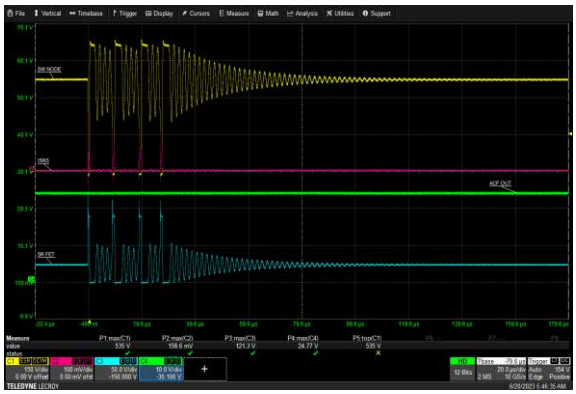


CSA: 265 Vac, 9V/3A USB-C1



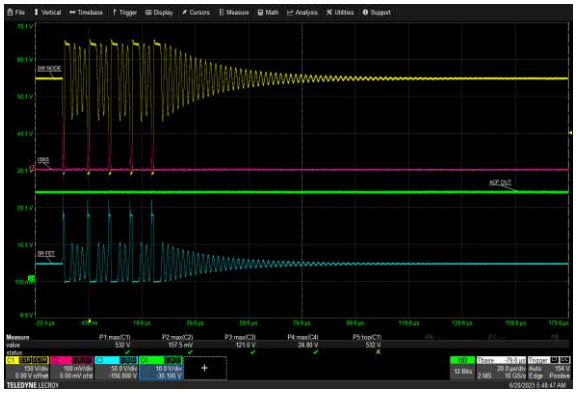
CSA: 265 Vac, 12V/0A USB-C1

CSA: 265 Vac, 12V/3A USB-C1

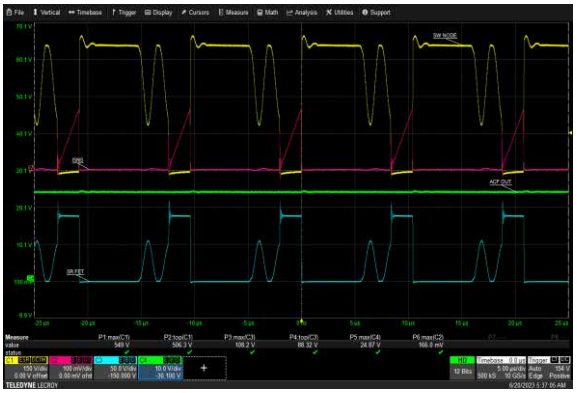


CSA: 265 Vac, 15V/0A USB-C1

CSA: 265 Vac, 15V/3A USB-C1



CSA: 265 Vac, 20V/0A USB-C1

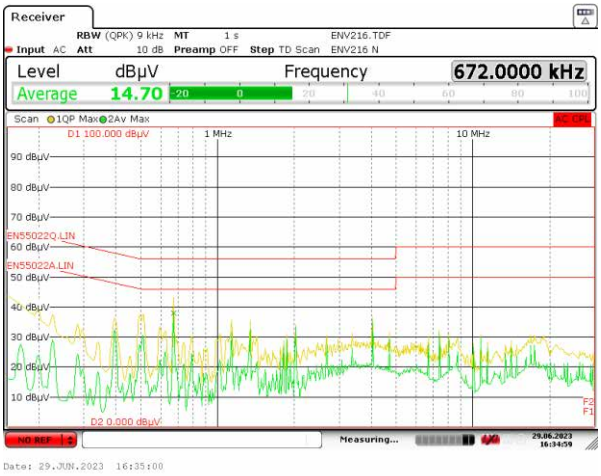


CSA: 265 Vac, 20V/3.25A USB-C1

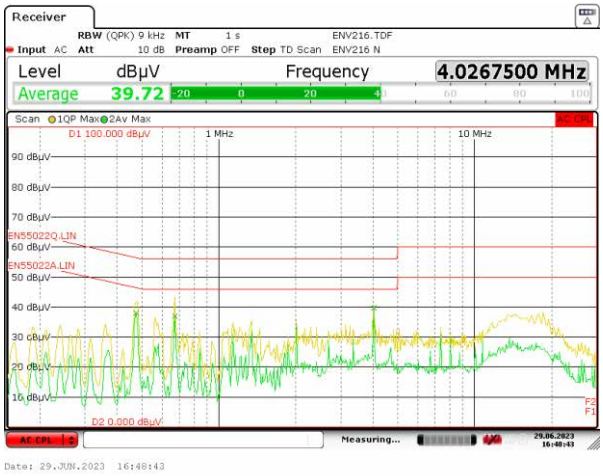
Conducted EMI Measurements

This section presents the conducted EMI emission measurements taken on the cased reference design. The tests were performed at different load conditions across the Master USB-C1 port, Slave USB-C2 port, and Slave USB-A1 port. The quasi-peak and average scans for combined line and neutral at 115 Vac and 230 Vac inputs are shown.

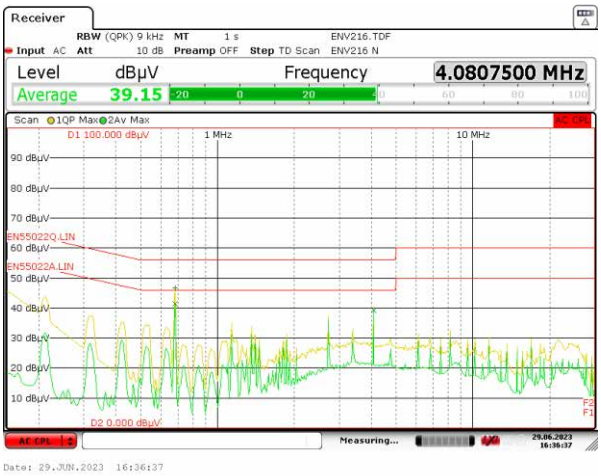
Figure 29. Conducted EMI Setup



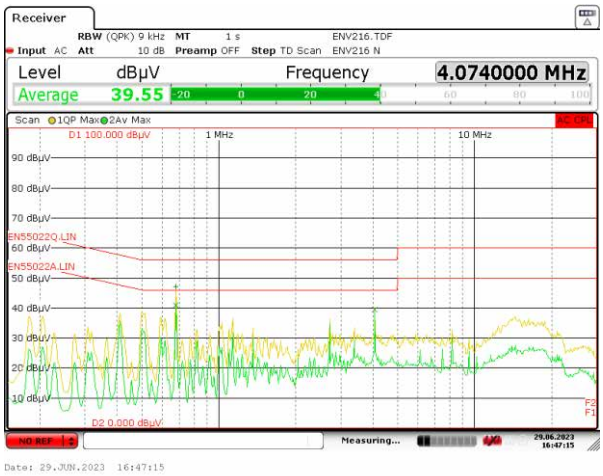
Conducted EMI: 115 Vac, 5V/3A (USB-C1) Margin: 8.14dB



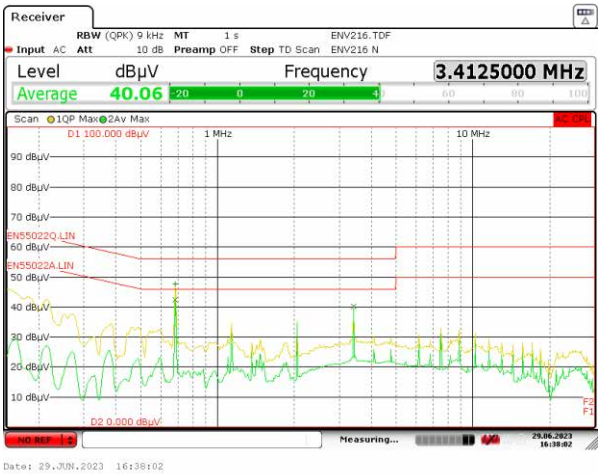
Conducted EMI: 230 Vac, 5V/3A (USB-C1) Margin: 6.4dB



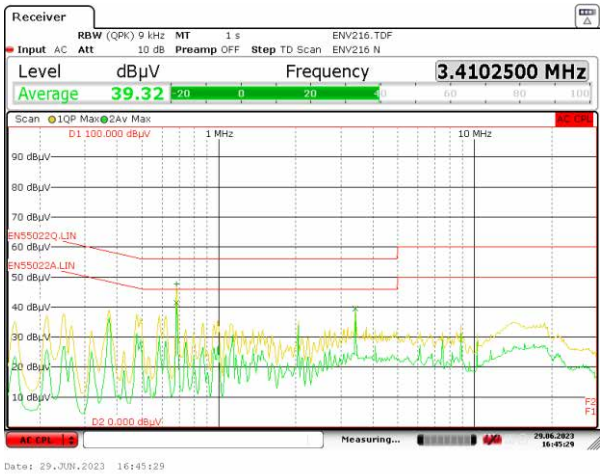
Conducted EMI: 115 Vac, 9V/3A (USB-C1) Margin: 4.55dB



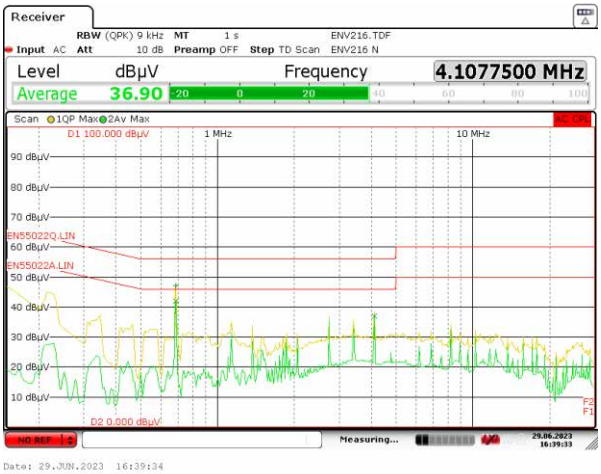
Conducted EMI: 230 Vac, 9V/3A (USB-C1) Margin: 5.02dB



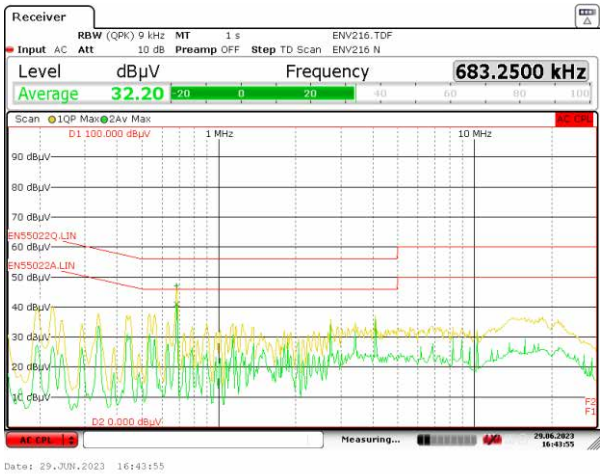
Conducted EMI: 115 Vac, 12V/3A (USB-C1) Margin: 3.47dB



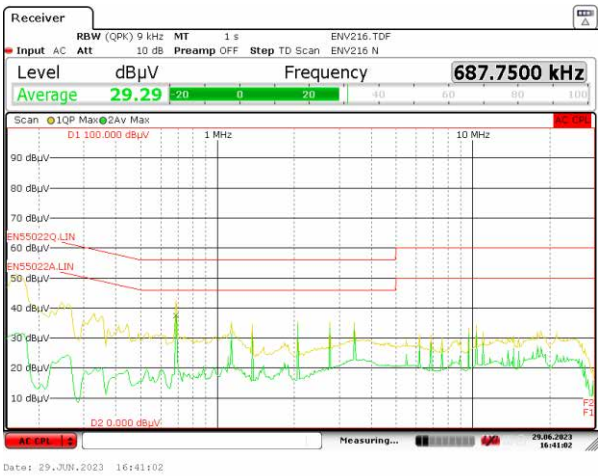
Conducted EMI: 230 Vac, 12V/3A (USB-C1) Margin: 4.5dB



Conducted EMI: 115 Vac, 15V/3A (USB-C1) Margin: 4.09dB

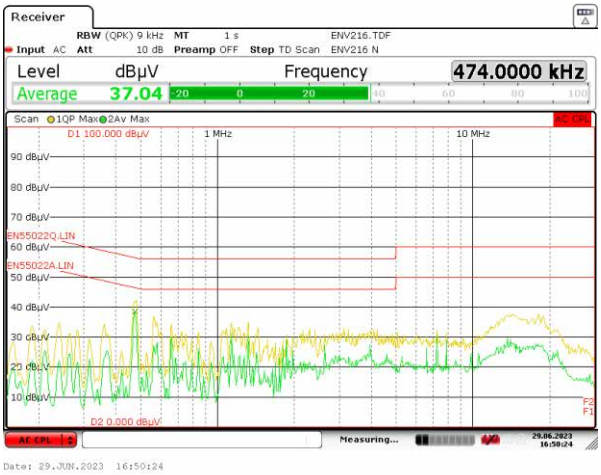


Conducted EMI: 230 Vac, 15V/3A (USB-C1) Margin: 4.97dB

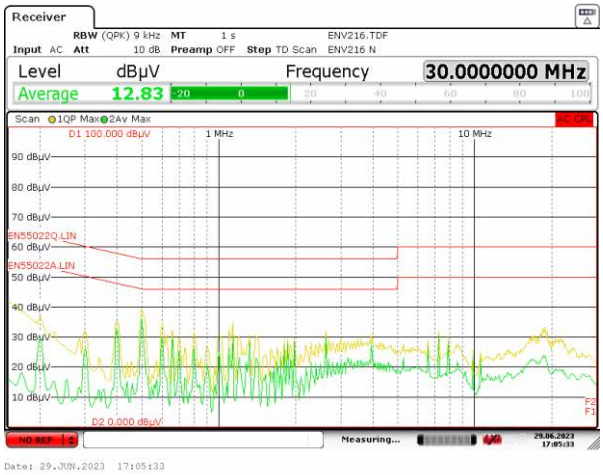


Conducted EMI: 115 Vac, 20V/3.25A (USB-C1) Margin: 8.6dB

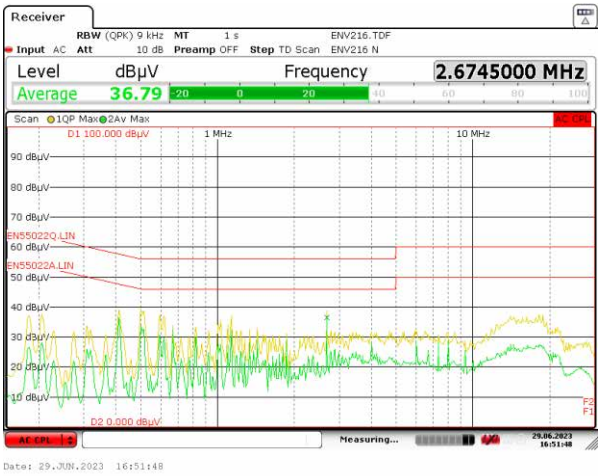
Conducted EMI: 230 Vac, 20V/3.25A (USB-C1) Margin: 9.8dB



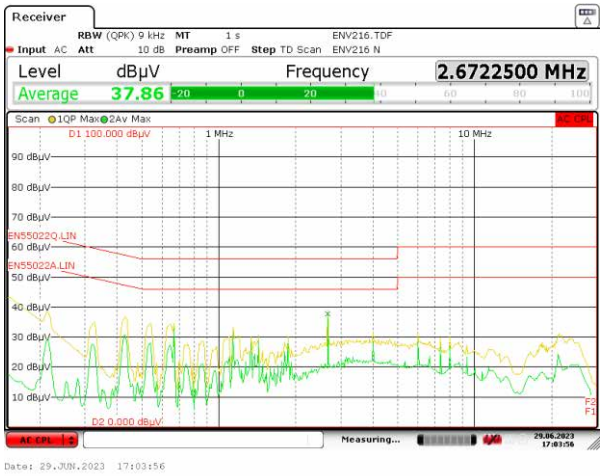
Conducted EMI: 115 Vac, 5V/3A (USB-C2) Margin: 8.04dB



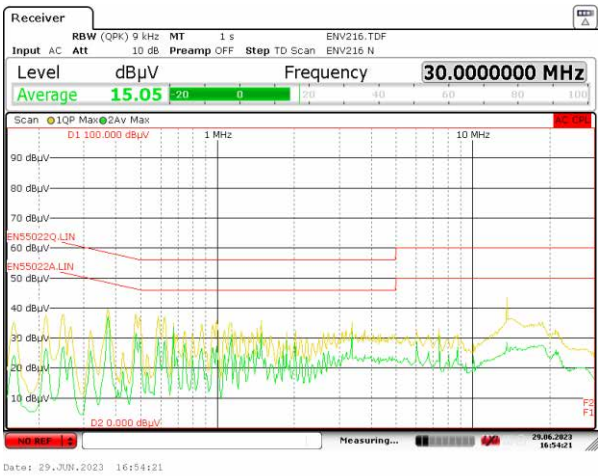
Conducted EMI: 230 Vac, 5V/3A (USB-C2) Margin: >10dB



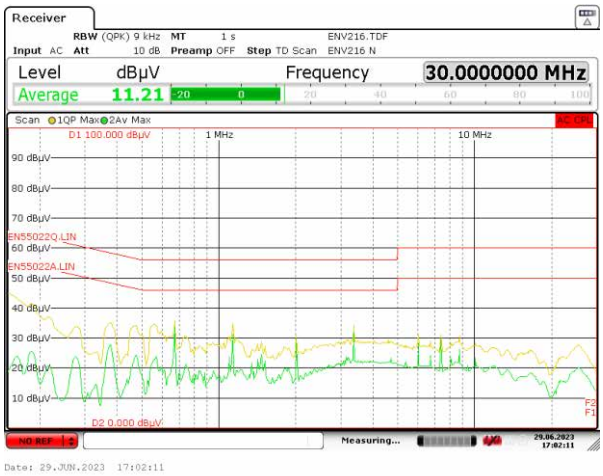
Conducted EMI: 115 Vac, 9V/3A (USB-C2) Margin: 9.50dB



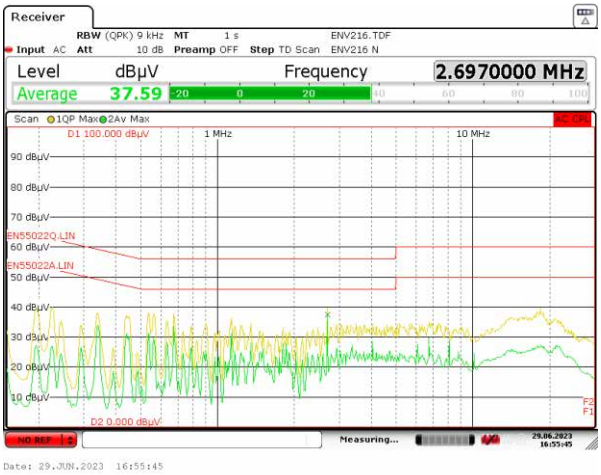
Conducted EMI: 230 Vac, 9V/3A (USB-C2) Margin: 8.35dB



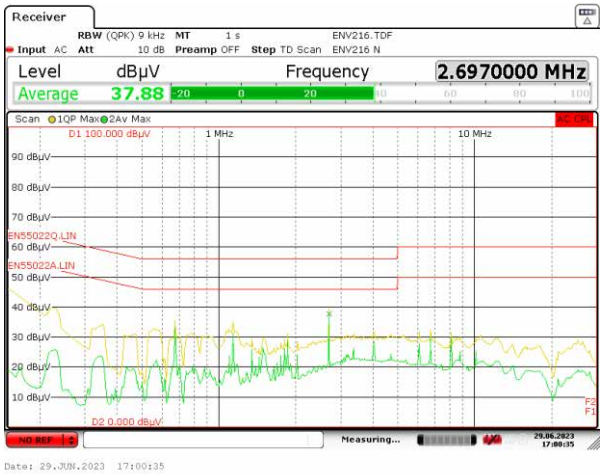
Conducted EMI: 115 Vac, 12V/3A (USB-C2) Margin: >10dB



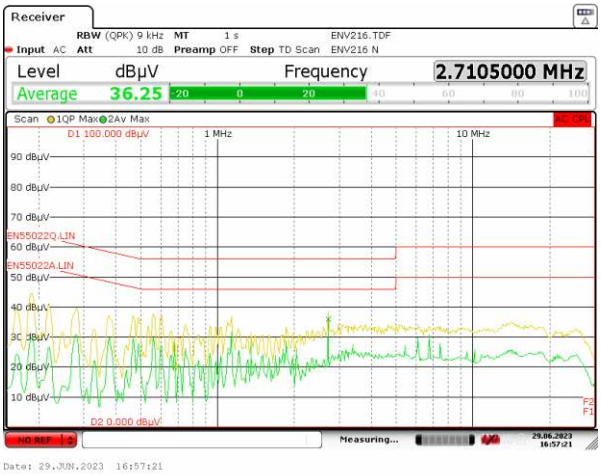
Conducted EMI: 230 Vac, 12V/3A (USB-C2) Margin: >10dB



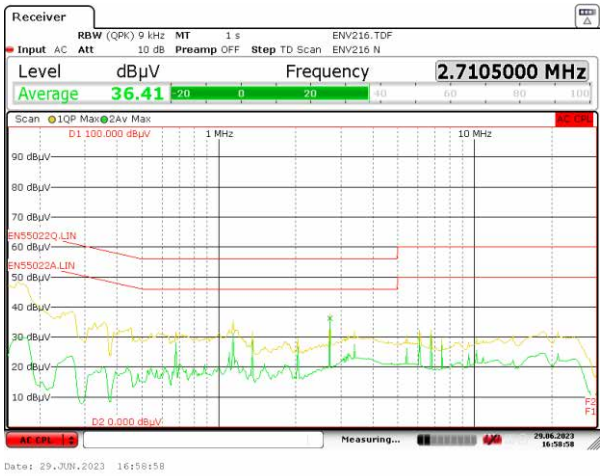
Conducted EMI: 115 Vac, 15V/3A (USB-C2) Margin: 8.64dB



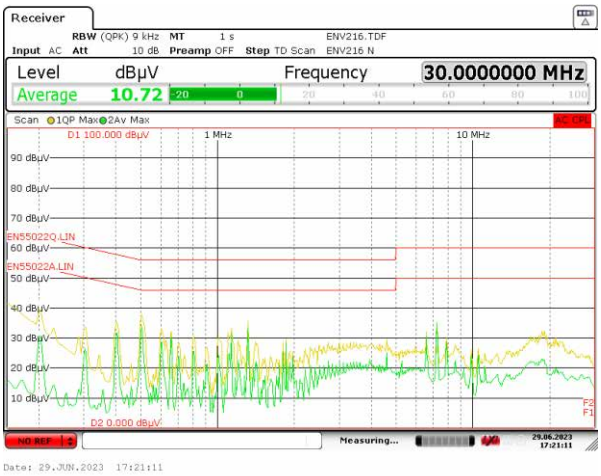
Conducted EMI: 230 Vac, 15V/3A (USB-C2) Margin: 8.37dB



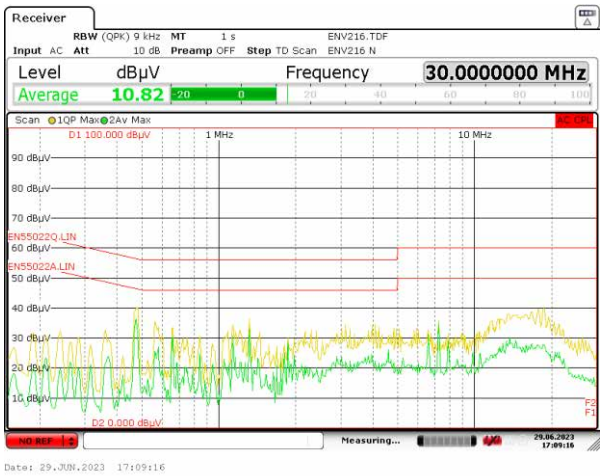
Conducted EMI: 115 Vac, 20V/3.25A (USB-C2) Margin: >10dB



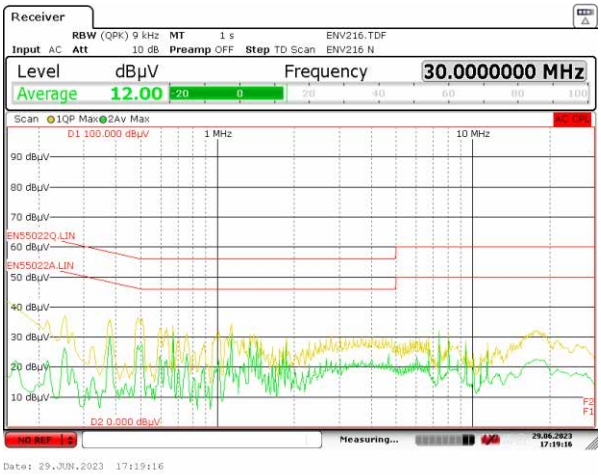
Conducted EMI: 230 Vac, 20V/3.25A (USB-C2) Margin: 9.9dB



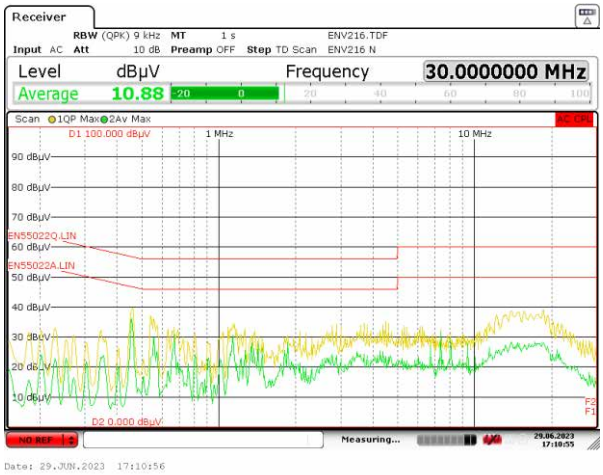
Conducted EMI: 115 Vac, 5V/3A (USB-A1) Margin: >10dB



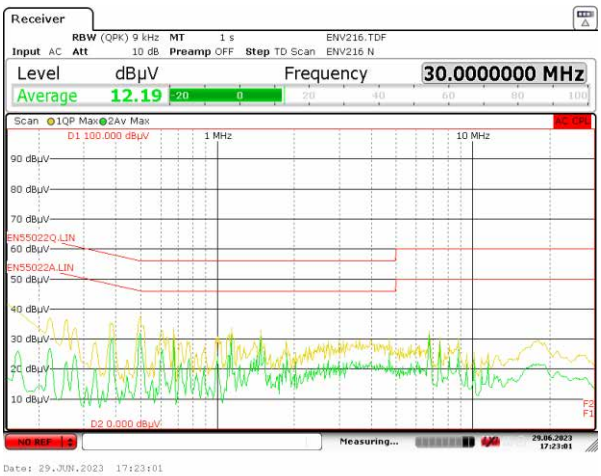
Conducted EMI: 230 Vac, 5V/3A (USB-A1) Margin: >10dB



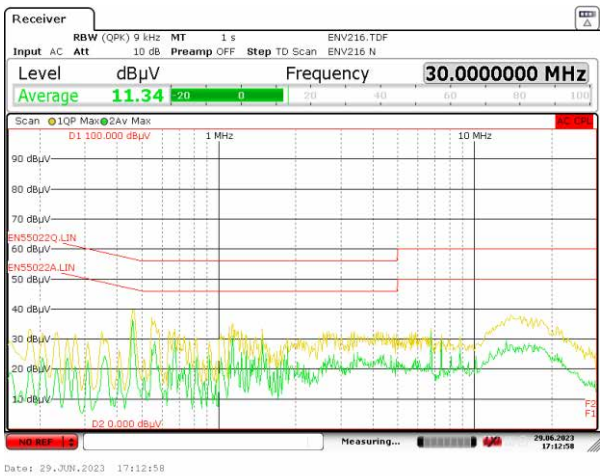
Conducted EMI: 115 Vac, 9V/2A (USB-A1) Margin: >10dB



Conducted EMI: 230 Vac, 9V/2A (USB-A1) Margin: >10dB



Conducted EMI: 115 Vac, 12V/1.5A (USB-A1) Margin: >10dB



Conducted EMI: 230 Vac, 12V/1.5A (USB-A1) Margin: >10dB

Radiated EMI Measurements

This section presents the radiated EMI emission measurements taken on the cased reference design. The tests were performed on a 10-meter Semi Anechoic Chamber (SAC) of an accredited third-party EMC test facility. The quasi-peak scans for combined horizontal and vertical polarizations at 115 Vac and 230 Vac inputs with different load conditions across the Master USB-C1 port, Slave USB-C2 port, and Slave USB-A1 port are shown.

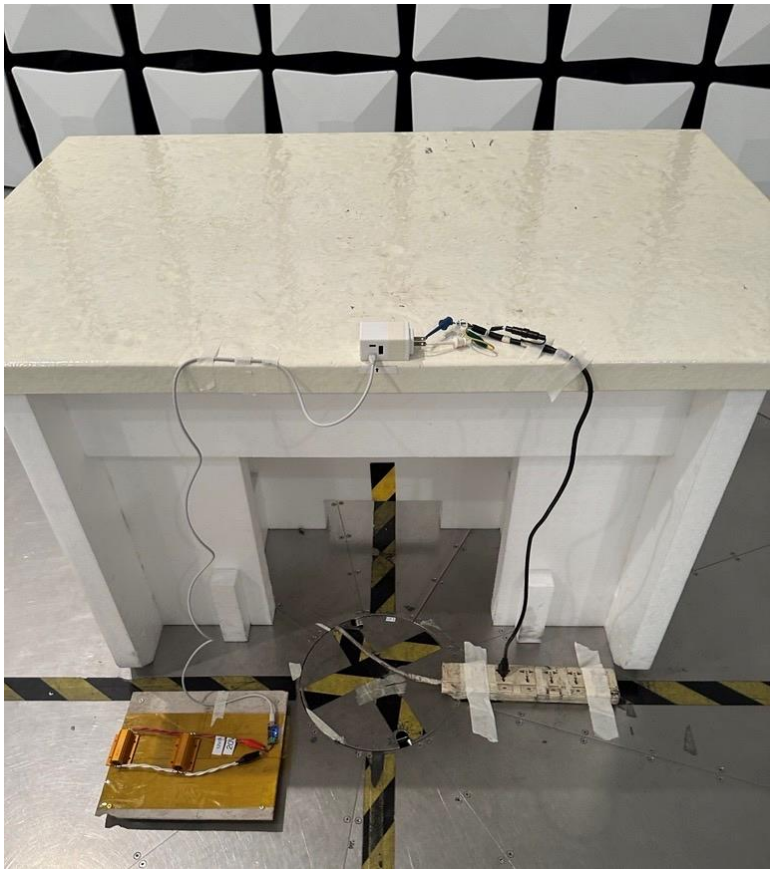
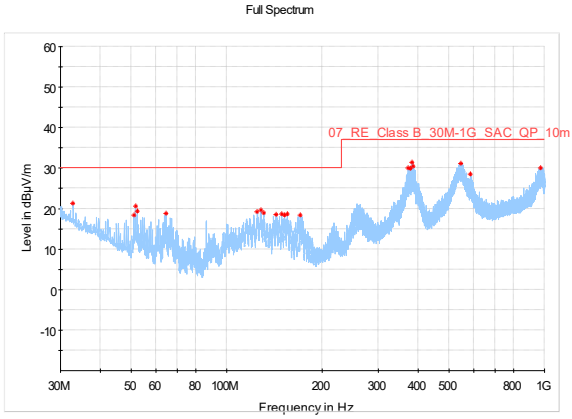
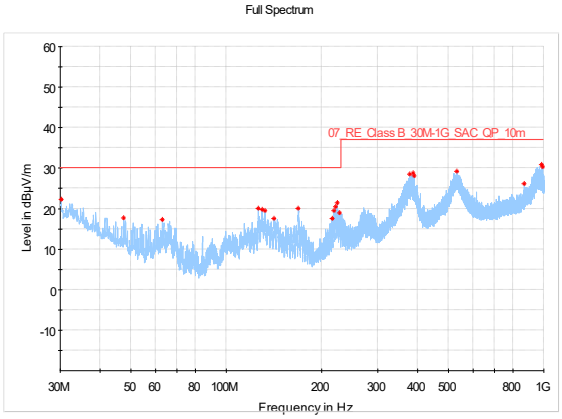


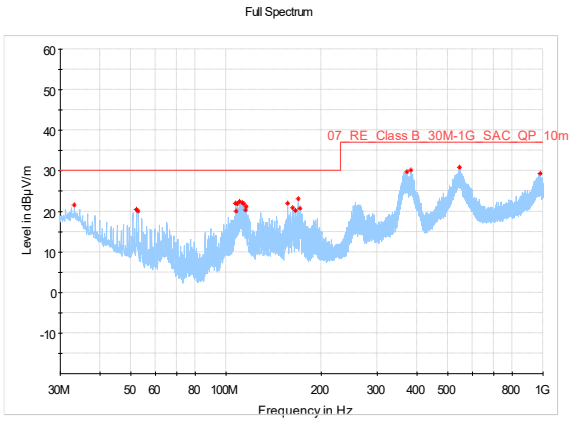
Figure 30. Radiated EMI Setup



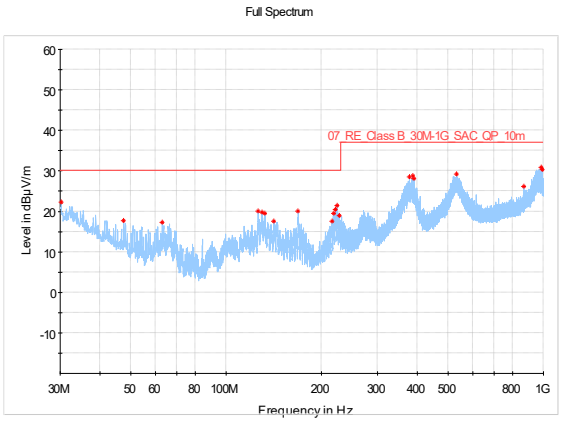
Radiated EMI: 115 Vac, 5V/3A (USB-C1) → Margin: 5.56dB



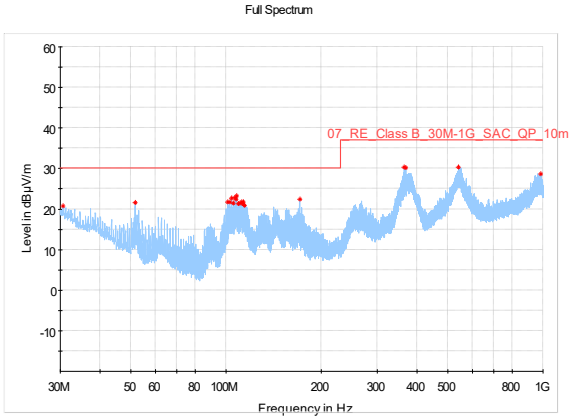
Radiated EMI: 230 Vac, 5V/3A (USB-C1) Margin: 6.08dB



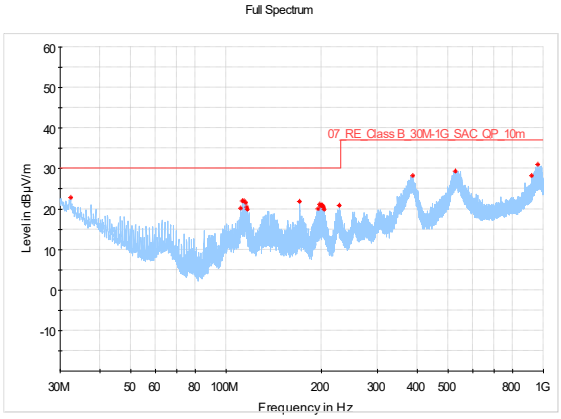
Radiated EMI: 115 Vac, 9V/3A (USB-C1) Margin: 6.14dB



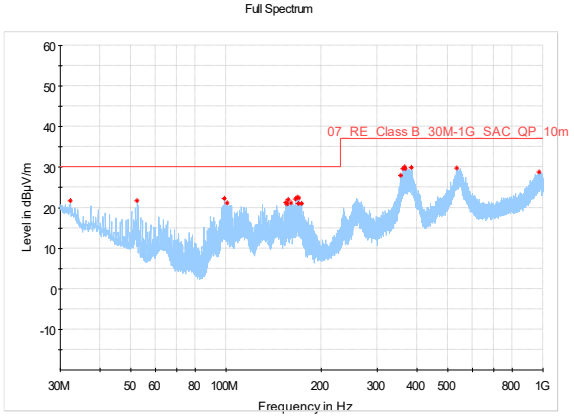
Radiated EMI: 230 Vac, 9V/3A (USB-C1) Margin: 4.30dB



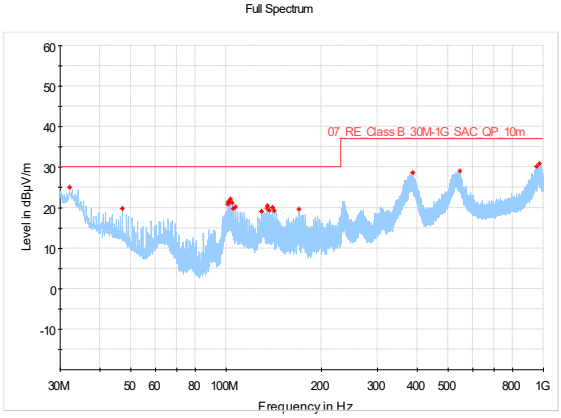
Radiated EMI: 115 Vac, 12V/3A (USB-C1) Margin: 6.71dB



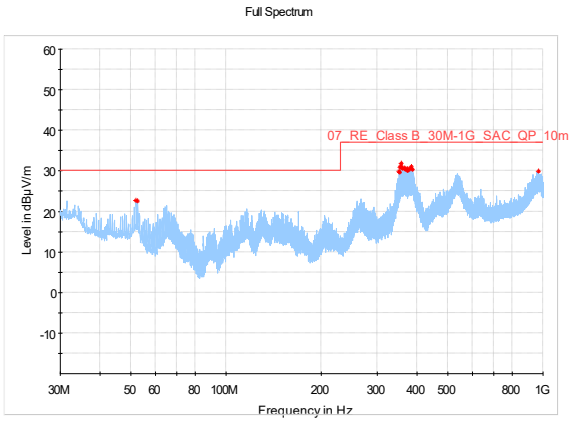
Radiated EMI: 230 Vac, 12V/3A (USB-C1) Margin: 5.99dB



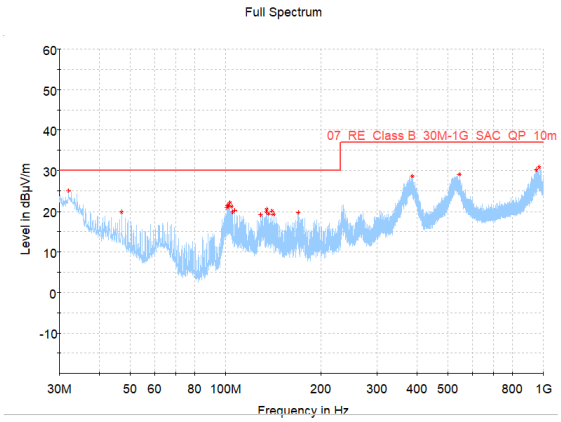
Radiated EMI: 115 Vac, 15V/3A (USB-C1) Margin: 7.07dB



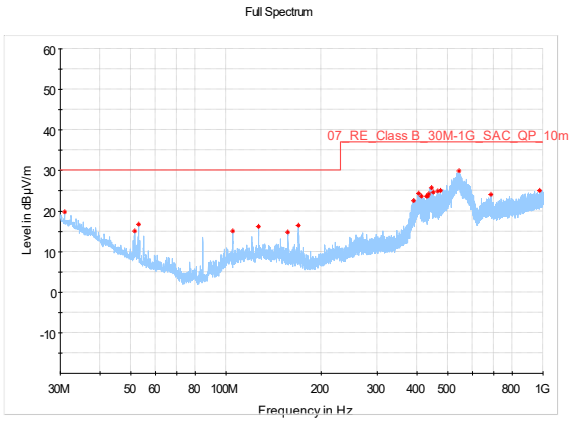
Radiated EMI: 230 Vac, 15V/3A (USB-C1) Margin: 4.99dB



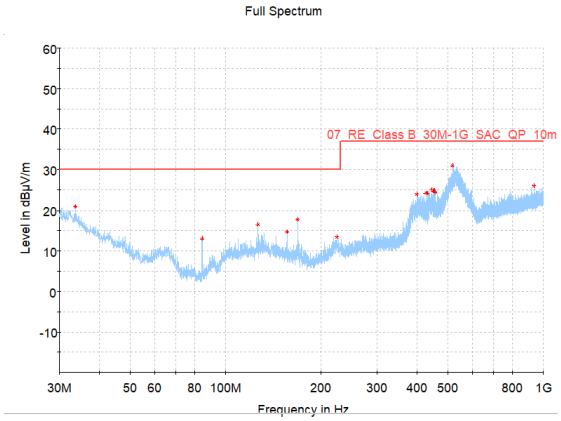
Radiated EMI: 115 Vac, 20V/3.25A (USB-C1) Margin: 5.20dB



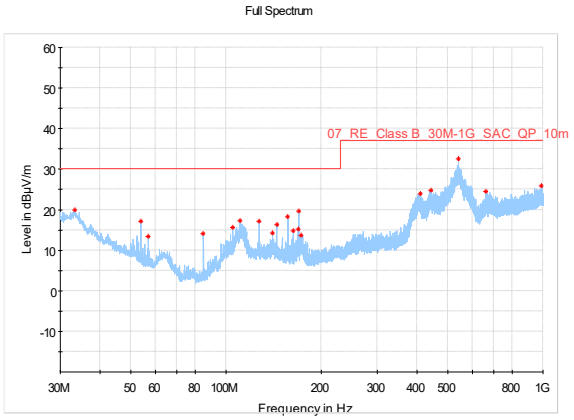
Radiated EMI: 230 Vac, 20V/3.25A (USB-C1) Margin: 5.32dB



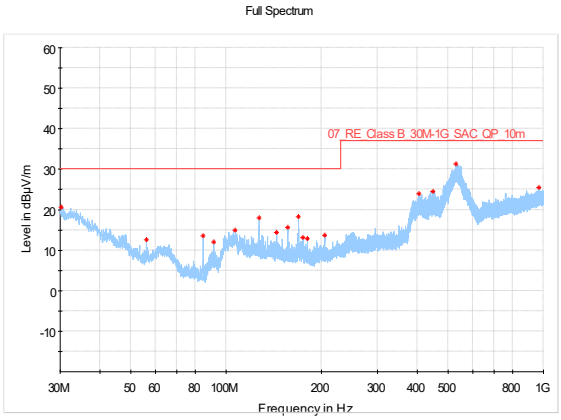
Radiated EMI: 115 Vac, 5V/3A (USB-C2) Margin: 7.05dB



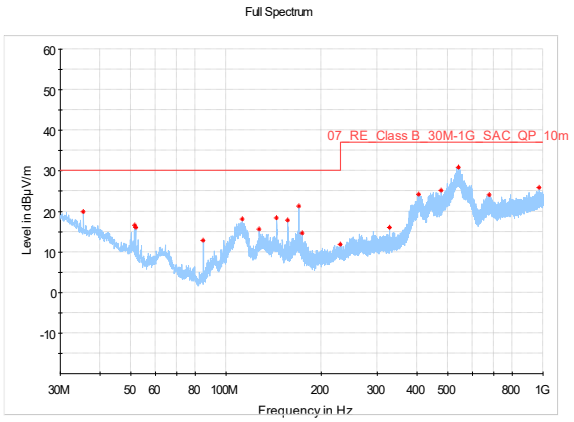
Radiated EMI: 230 Vac, 5V/3A (USB-C2) Margin:5.98dB



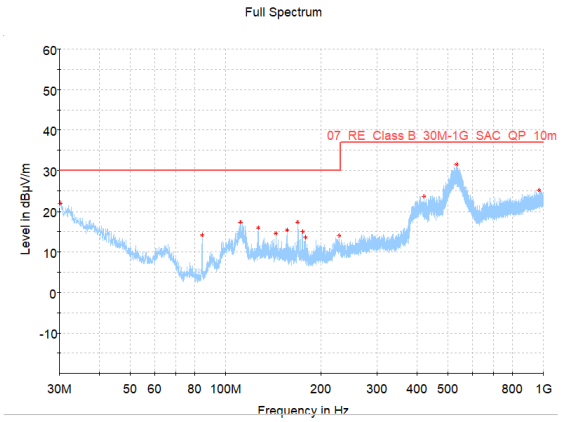
Radiated EMI: 115 Vac, 9V/3A (USB-C2) Margin: 4.40dB



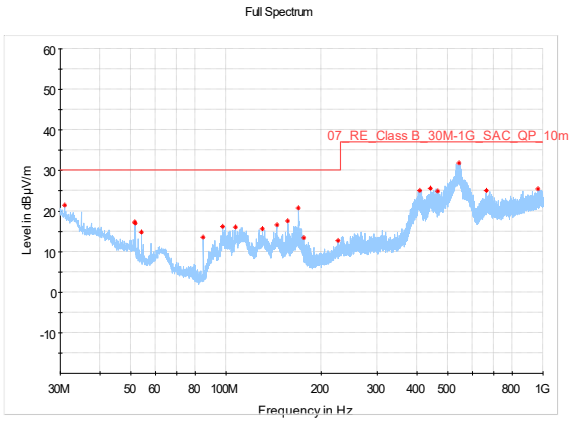
Radiated EMI: 230 Vac, 9V/3A (USB-C2) Margin: 5.64dB



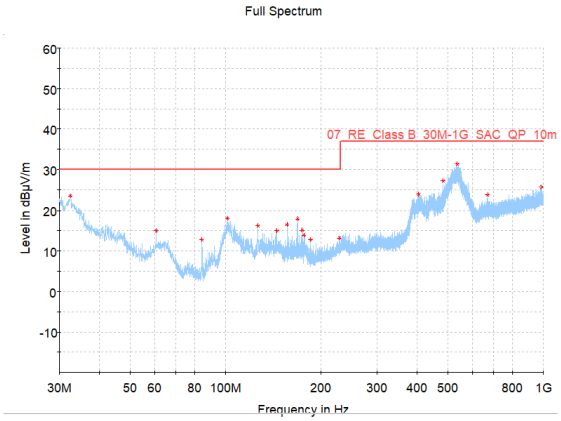
Radiated EMI: 115 Vac, 12V/3A (USB-C2) Margin: 6.16dB



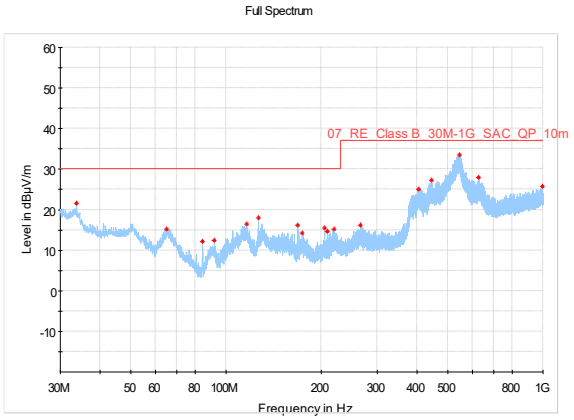
Radiated EMI: 230 Vac, 12V/3A (USB-C2) Margin: 5.40dB



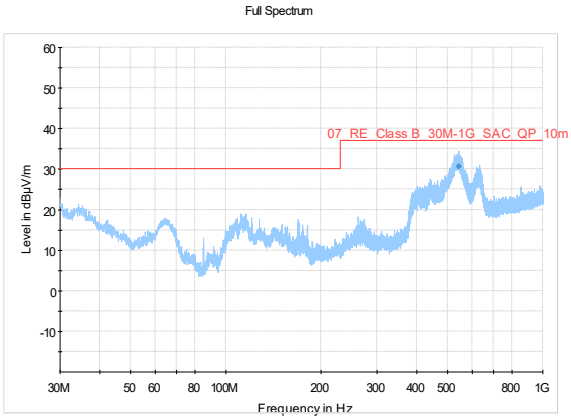
Radiated EMI: 115 Vac, 15V/3A (USB-C2) Margin: 5.19dB



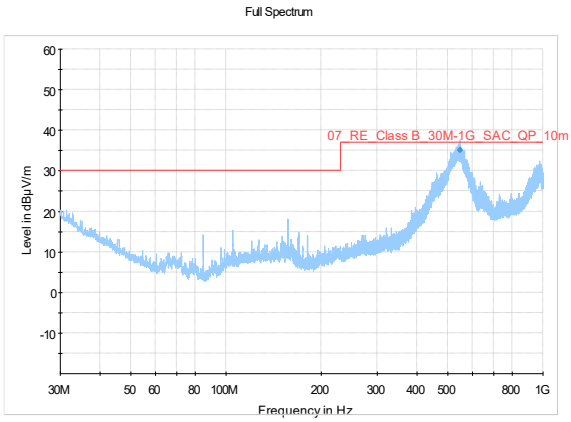
Radiated EMI: 230 Vac, 15V/3A (USB-C2) Margin: 5.62dB



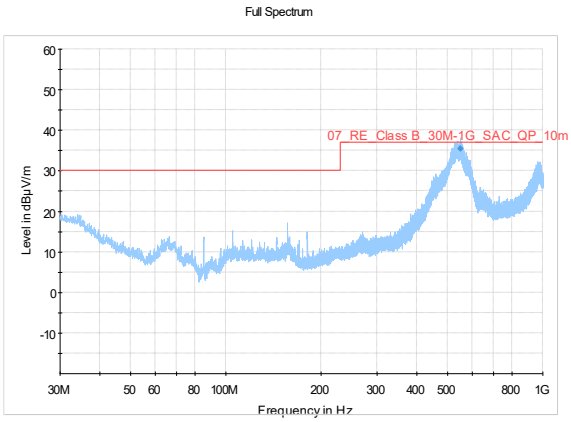
Radiated EMI: 115 Vac, 20V/3.25A (USB-C2) Margin: 3.46dB



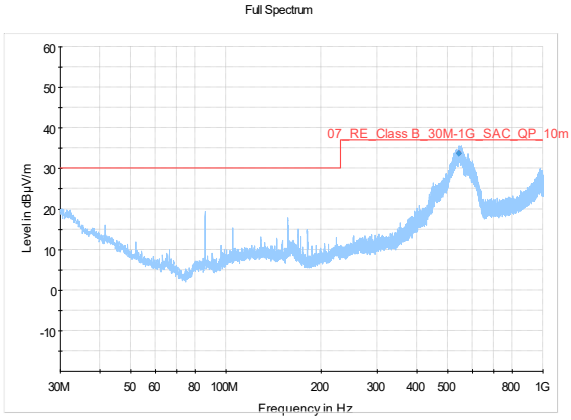
Radiated EMI: 230 Vac, 20V/3.25A (USB-C2) Margin: 6.46dB



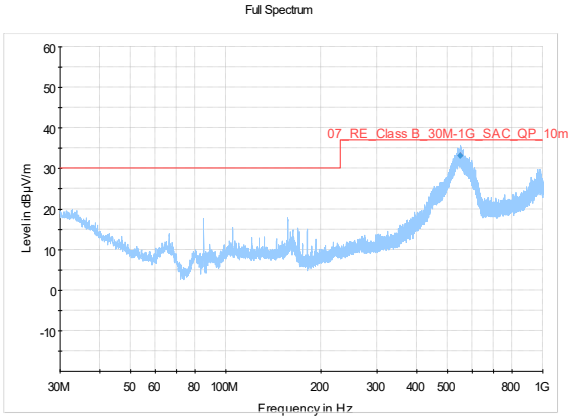
Radiated EMI: 115 Vac, 5V/3A (USB-A1) Margin: 2.01dB



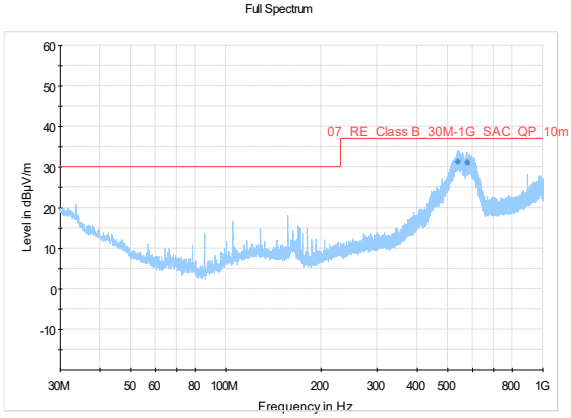
Radiated EMI: 230 Vac, 5V/3A (USB-A1) Margin:1.52dB



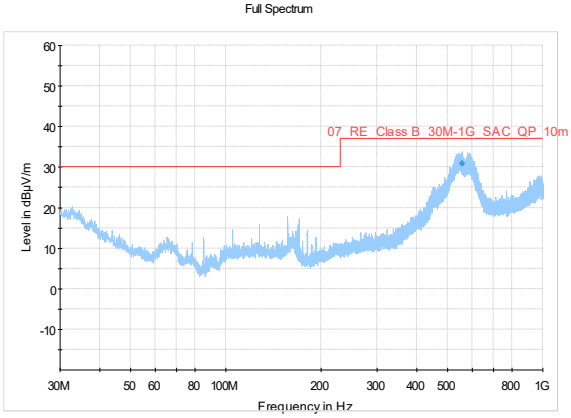
Radiated EMI: 115 Vac, 9V/2A (USB-A1) Margin: 3.30dB



Radiated EMI: 230 Vac, 9V/2A (USB-A1) Margin: 3.83dB



Radiated EMI: 115 Vac, 12V/1.5A (USB-A1) Margin: 5.68dB

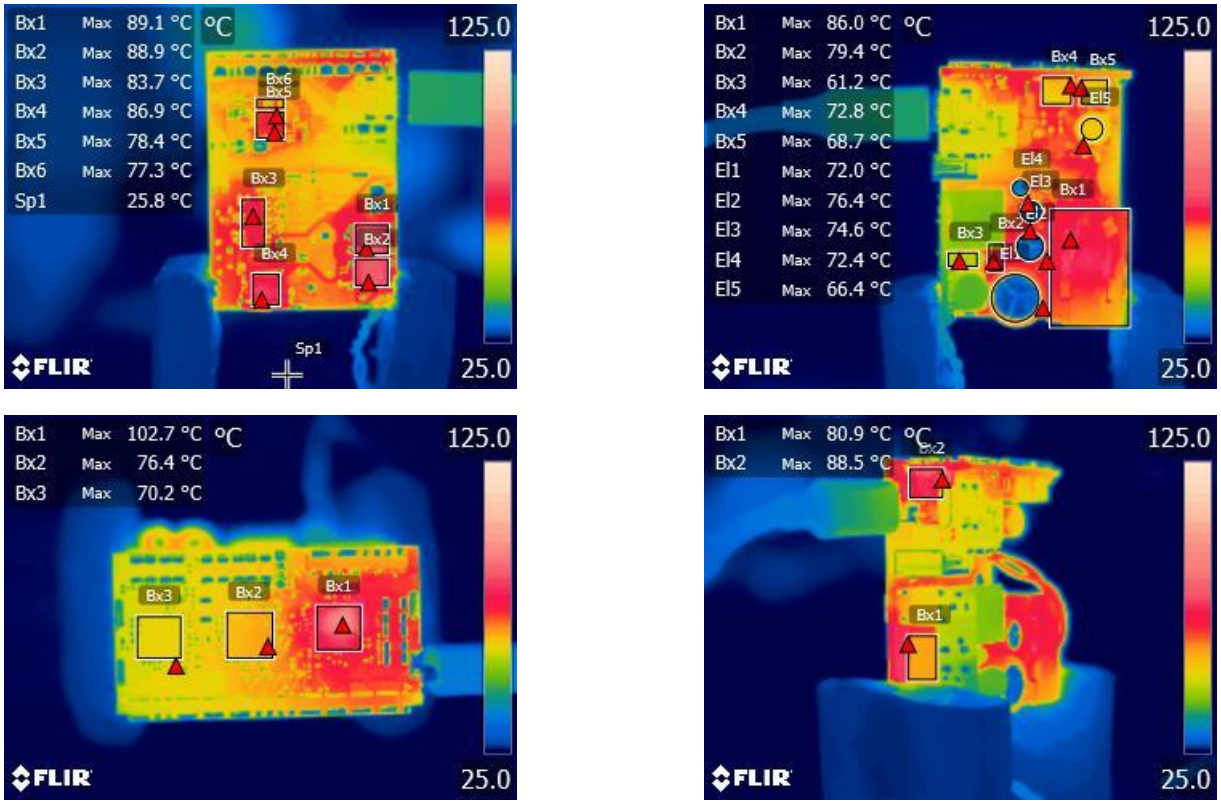


Radiated EMI: 230 Vac, 12V/1.5A (USB-A1) Margin: 6.15dB

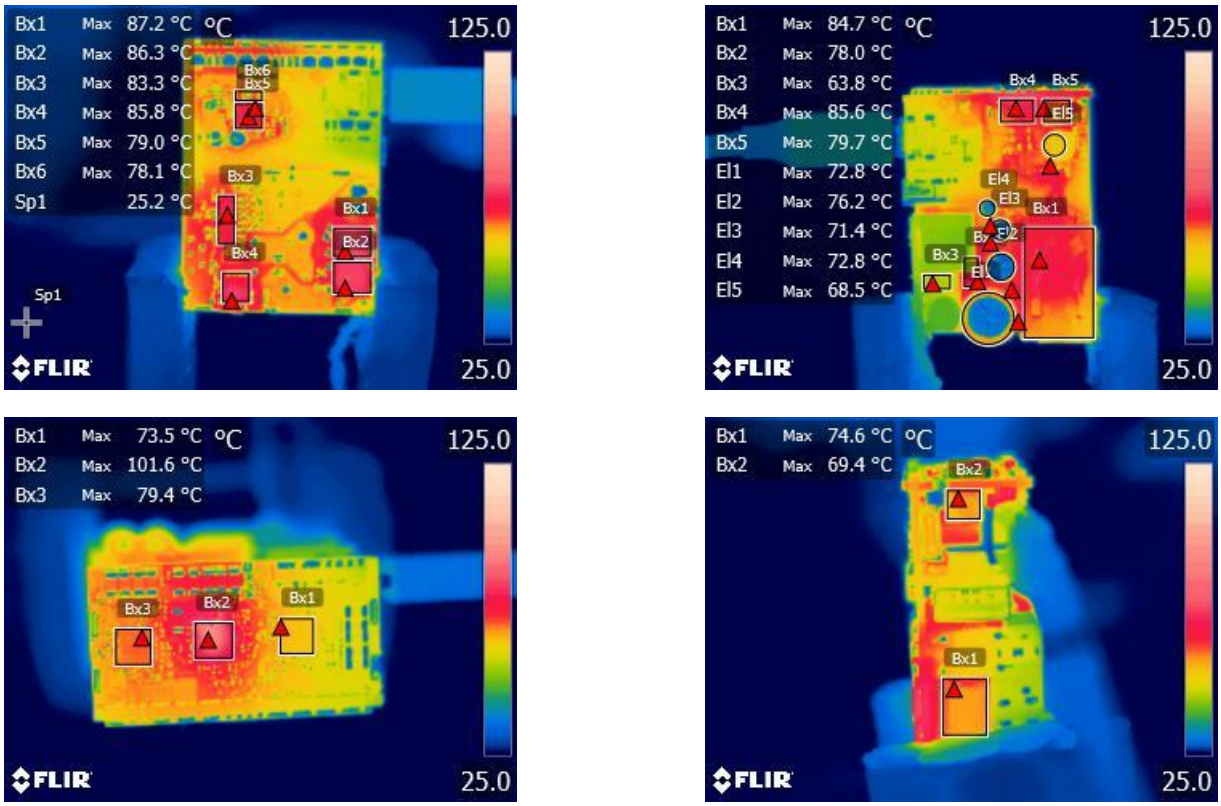
Thermal Measurements (Thermal IR Imaging – Uncased Unit)

This section covers the thermal measurements of the uncased reference design. Thermal IR imaging of the critical components on the board were recorded at room ambient temperature during full power operation on 90 Vac and 265 Vac input.

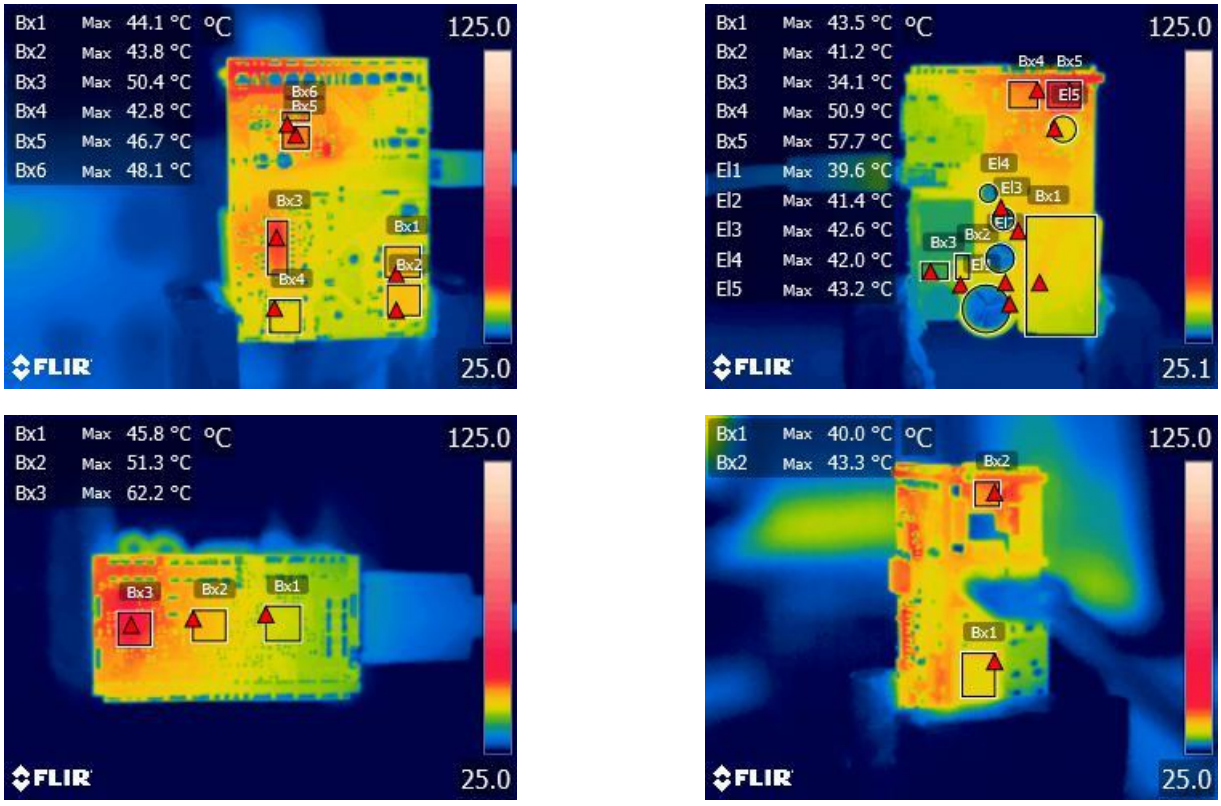
Ref Des	Description	Master USB-C1 90 Vac, 65 W 20V/3.25A	Slave USB-C2 90 Vac, 65 W 20V/3.25A	Slave USB-A1 90 Vac, 18 W 9V/2A	Master USB-C1 265 Vac, 65 W 20V/3.25A
U2	SZ1131-00	83.7°C	83.3°C	50.4°C	76.2°C
Q2	Primary FET (TP65H300G4JSGB)	86.9°C	85.8°C	42.9°C	75.4°C
BR1	Bridge Rectifier 1	89.1°C	87.2°C	44.1°C	58.9°C
BR2	Bridge Rectifier 2	88.9°C	86.3°C	43.8°C	59.5°C
Q1	SR FET	78.4°C	79.0°C	46.7°C	75.0°C
R33	SR FET Snubber	77.3°C	78.1°C	48.1°C	78.8°C
T1	ACF Transformer	86.0°C	84.7°C	43.5°C	72.6°C
L1	Differential Choke	79.4°C	78.0°C	41.2°C	60.7°C
C1	Bulk Capacitor	80.9°C	74.6°C	40.0°C	55.1°C
C2	Bulk Capacitor	72.0°C	72.8°C	39.6°C	59.2°C
C3	Bulk Capacitor	76.4°C	76.2°C	41.4°C	61.4°C
C26	VCC1 Aux Capacitor	74.6°C	71.4°C	42.6°C	64.5°C
C23	VCC Aux Capacitor	72.4°C	72.8°C	42.0°C	62.4°C
C7	ACF Output Capacitor	66.4°C	68.5°C	43.2°C	68.0°C
DC-DC L1	Master C Buck Choke	88.5°C	74.6°C	43.3°C	86.3°C
DC-DC L3	Slave C Buck Choke	72.8°C	85.6°C	50.9°C	68.5°C
DC-DC L2	Slave A Buck Choke	61.2°C	78.0°C	57.7°C	63.8°C
DC-DC U1	Master C SZPL3002A	102.7°C	73.5°C	45.8°C	101.9°C
DC-DC U3	Slave C SZPL3002A	76.4°C	101.6°C	51.3°C	73.2°C
DC-DC U3	Slave C SZPL3002A	70.2°C	79.4°C	62.2°C	68.6°C



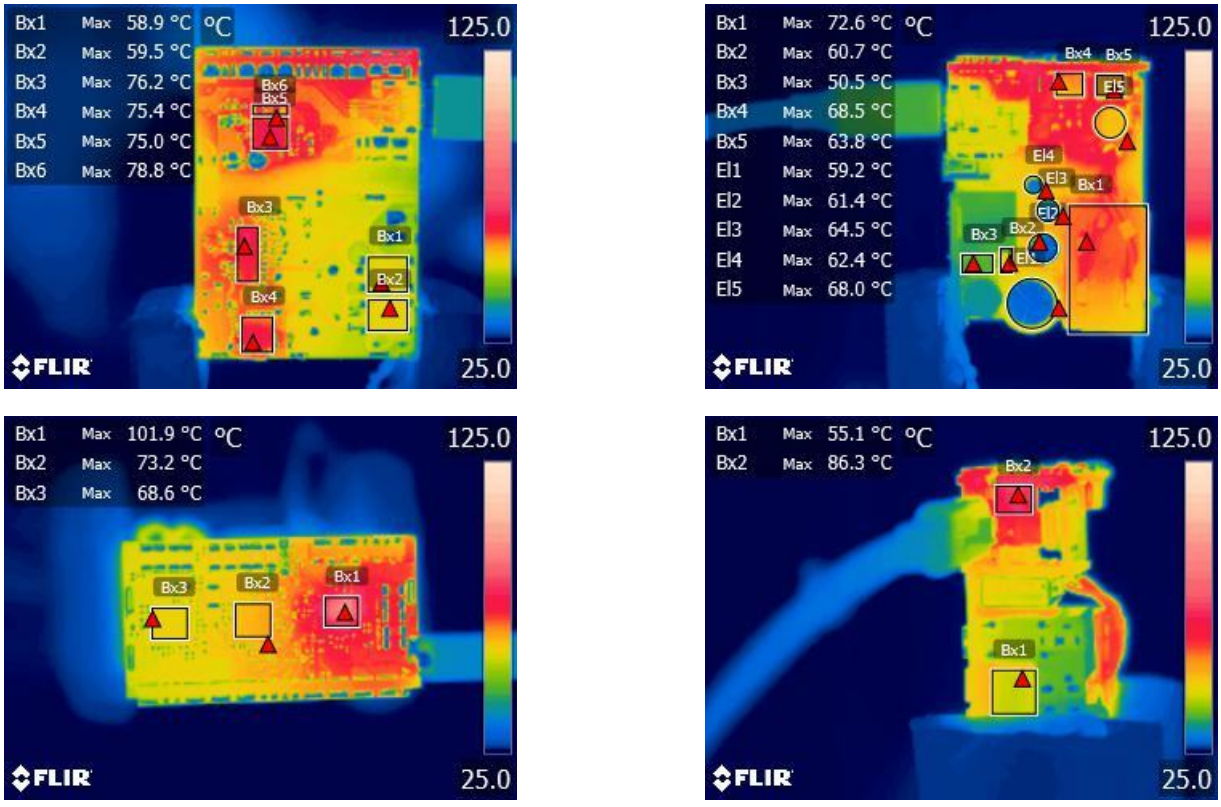
Thermal IR Imaging (Uncased) 90 Vac, 65 W 20V/3.25A (USB-C1)



Thermal IR Imaging (Uncased) 90 Vac, 65 W 20V/3.25A (USB-C2)



Thermal IR Imaging (Uncased) 90 Vac, 18 W 9V/2A (USB-A1)

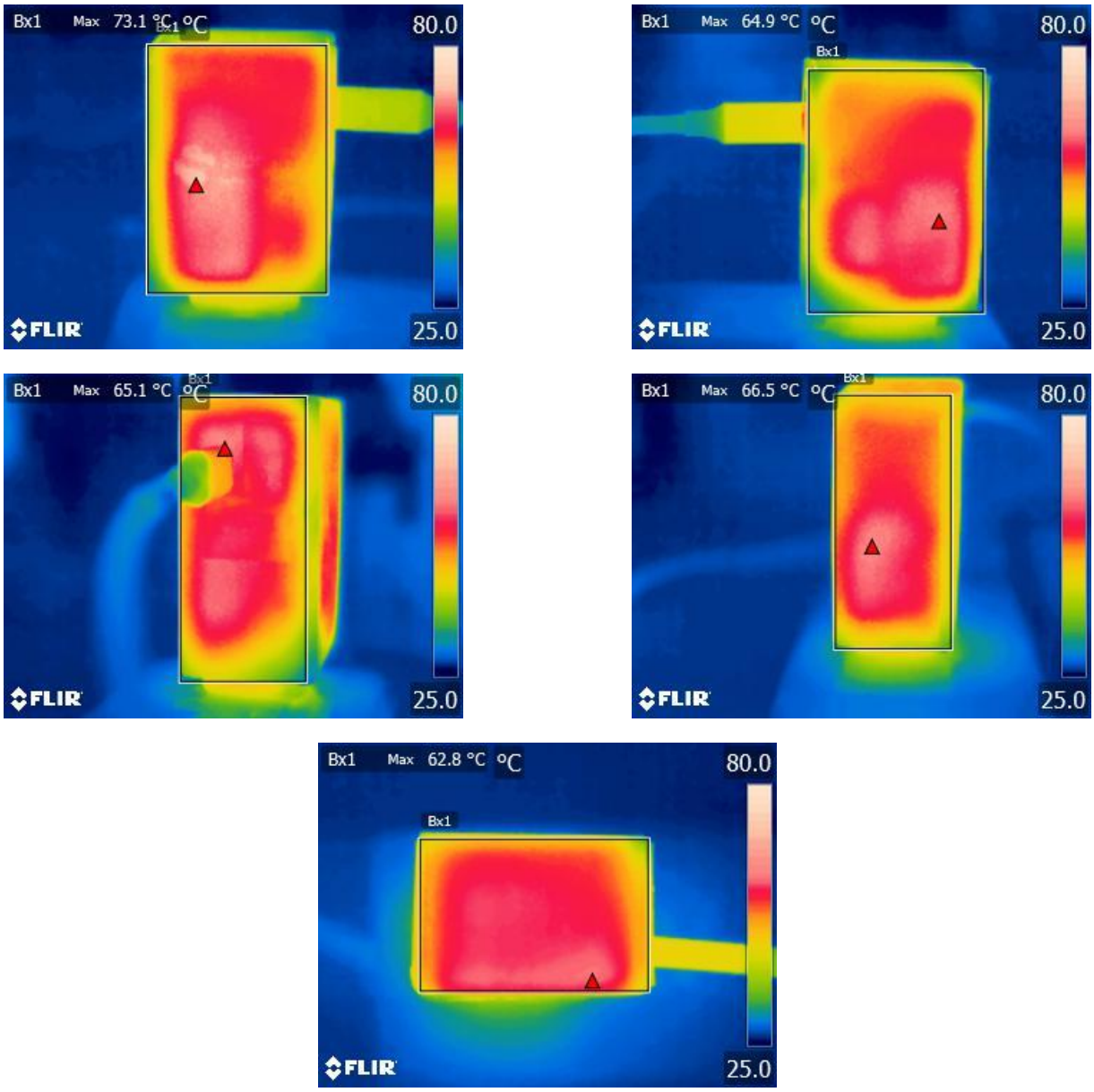


Thermal IR Imaging (Uncased) 265 Vac, 65 W 20V/3.25A (USB-C1)

Thermal Measurements (Touch Temperature – Cased Unit)

This section covers the thermal measurements of the touch temperature on the cased reference design. Thermal IR imaging of the different sides of the cased unit were recorded at room ambient temperature during full power operation on 100 Vac input after one hour soak time.

Cased Unit	Description	Master USB-C1 100 Vac, 65 W 20V/3.25A
Side 1	DC-DC Board Side	62.8°C
Side 2	Mainboard-Solder Side	73.1°C
Side 3	Mainboard-Component Side	64.9°C
Side 4	Mainboard-TRF Side	66.5°C
Side 5	USB Ports Side	65.1°C



Thermal IR Imaging (Touch Temperature) 100 Vac, 65 W 20V/3.25A (USB-C1)

Revision History

Revision	Date	Author	Note
1.0	07/07/2023	CE	Results collected and report generated.